Eating Patterns and Food Systems: Critical Knowledge Requirements for Policy Design and Implementation

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Abstract: The paper highlights the extent to which eating patterns are important for building agricultural and food systems. It presents the main features of eating patterns worldwide (relative convergence of diets, more rapid food transitions in emerging and developing countries and substantial food losses and waste at distribution and final consumption stages). These patterns have negative consequences on health and the environment. Their drivers are then examined to identify knowledge gaps, which if filled, should facilitate the design and implementation of actions and policies aimed at making food systems more sustainable.

1. Introduction

According to the 1996 World Food Summit, "food security at the individual, household, national, regional and global levels is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." (FAO 1996). This definition broadens the initial focus of the 1974 World Food Summit (United Nations 1974) on the volume and stability of food supplies, by including secured access for all people, especially the most vulnerable, to available supplies, and by incorporating food safety and nutritional balance. The 1996 definition also reflects concerns about food composition and nutrient requirements for an active and healthy life.

Global food is clearly insecure. According to FAO (2010), 925 million people were undernourished in 2010. Furthermore, many people were affected by vitamin and mineral deficiencies - one out of three in developing countries according to the WHO (WHO on line). At the same time, 1.5 billion adults were overweight in 2008, including over 200 million obese men and nearly 300 million obese women (WHO 2011). In addition, a growing number of low and middle-income countries are facing a double burden of malnutrition, i.e., the persistence of under-nutrition, notably among children, along with a rapid rise in overweight and obesity, and diet-related chronic diseases.

Food security is not just about supply matching demand. The development of agricultural and food systems must be viewed in the context of sustainable development. It must take into account the progressive depletion of fossil energy, the protection of soil and water resources, the preservation of biodiversity and the issue of climate change. If they are to feed more than nine billion people by 2050, farmers around the world will have to produce crops using less fossil fuel in an environmentally friendly way. They will also have to provide energy and industrial commodities in place of

petrochemical products, as well as environmental and rural services like water management, biodiversity protection, carbon sequestration, or diversified and open landscapes. In addition, food consumption habits will need to adapt. The foresight study Agrimonde (Paillard et al. 2010) clearly shows that by 2050 eating patterns will be a major issue for world food security. It shows in particular, that Westernized diets cannot be generalised throughout the planet.

In that general context, the objective of the paper is to highlight the extent to which eating patterns are important for building sustainable agricultural and food systems, a research and policy area which is too often underestimated in the literature, be it on food security or more generally on global challenges the world is facing. The focus on the sustainability of eating patterns does not mean that reducing hunger is not a priority. Poverty is the principal cause of hunger and at the same time, hunger is a cause of poverty and under-nutrition (FAO 2010). Reducing poverty and hunger are well documented in the literature (see, for example, FAO, IFAD & WFP 2002, or, more recently, IFAD 2011).

The rest of the paper is organized as follows. Section 2 presents the principal features of eating patterns worldwide, that is, the relative convergence of world food diets, more rapid food transitions in emerging and some developing countries, and substantial food waste and losses at distribution and final consumption stages. These common evolutions have negative consequences that are summarized in Section 3. The main drivers of these common eating patterns are then examined (Section 4) in order to make recommendations about knowledge gaps, which if filled, should facilitate the design and implementation of actions and policies aiming at making food systems more sustainable (Section 5). The final section concludes the paper.

2. Stylised facts

2.1. World eating patterns are converging

The food transition process characterising the convergence of eating patterns consists of two main steps. The first step is quantitative. The caloric intake increases with proportionally equal increases in all food products; the nutritional structure of the intake is stable. The second step, called 'diet transition', is qualitative. Once caloric saturation is achieved, diet structure changes: consumption of cereals and vegetables decreases while that of sugar, fats and animal products increases. Figure 1 illustrates this two-step process for the French case. As in many western European countries, the quantitative phase started with the agricultural and industrial revolution and developed through the 19th century, until around 1910-20. From that date, consumption of cereals and potatoes decreased while consumption of fats, oils, sugar, fruit, vegetables and animal products, which was already slightly increasing during the 19th century, grew faster (Figure 1, left panel a). Changes in food diet composition translate into changes in macro-nutriment weight. From 1880 to 1980, carbohydrates decreased from 70% to 45% of the total energy intake, whereas lipids jumped from 16% up to 42%; proteins remained constant (Figure 1, right panel b).

Developed countries achieved the second step of the food transition process over a century. Many emerging and developing countries in Asia, Central and Latin America, and to a lesser extent in

Africa, follow a similar pattern but at an accelerated pace, as the diet transition is reduced to 20 years in emerging countries and 40 years in developing countries (Popkin 2006). This is illustrated by Figure 2 which shows that an increasing number of countries are following a similar pattern when one compares the composition of dietary macronutrients in 1961-63 (left panel a) and 2001-03 (right panel b).

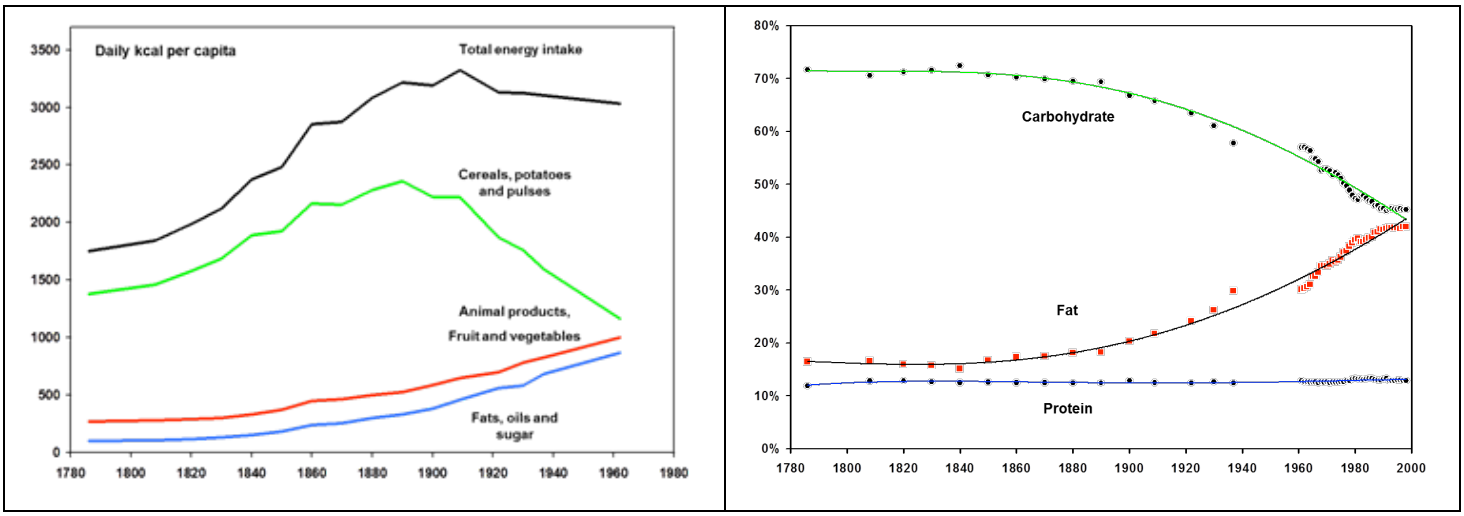
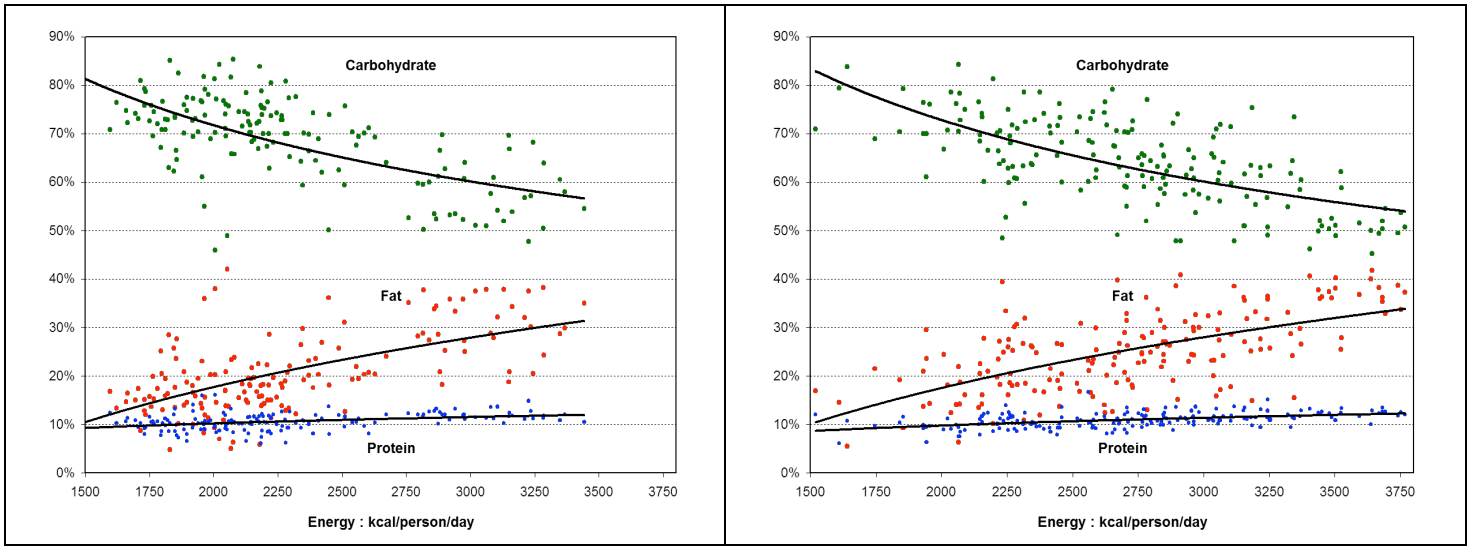


Figure 1
Secular trends in the daily caloric intake (left panel a) and in the structure of the diet in France (right panel b). Source: Combris (2006)



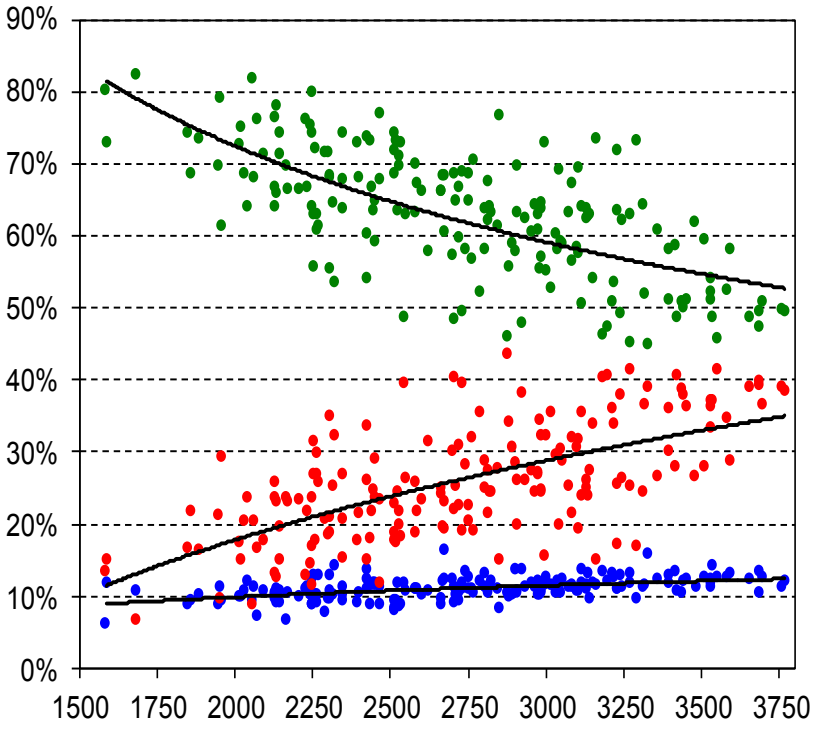


Figure 2

Structure of the world diet, 1961-63 (left panel a), 2001-03 (right panel b) and 2005-07 (low panel c). Source: Combris (2006) from the FAO Stat database for panels a and b; elaborated by Combris from the FAO Stat database for panel c

Figure 3 summarizes the food transition process on a two-axis graph illustrating the common trend towards both an increasing calorie intake and a growing share of animal products. Figure 3 also shows that convergence is not perfect. Diet differences remain between countries at the same level of economic development, as well as between households within the same country. These differences are also illustrated by Figure 4, which depicts beef, pork and poultry consumption in several European countries from 1960 to 2003. Although consumption gaps (measured by the ratio of per capita maximal consumption on minimal consumption) are reduced over time, individual meat consumption levels are still significantly different: in the case of beef, they range from 13 kg per person per year in Germany to more than 26 kg in France; in the case of pork, from 28 kg per person per year in the United Kingdom to 56 kg in Germany and 62 kg in Spain; in the case of poultry, from 15-16 kg per person per year in Germany and Italy to 28-29 kg in Spain and the United Kingdom. These gaps in meat consumption levels are important in so far as those three animal species have different impacts on the environment, notably in terms of greenhouse gas emissions (Combris et al. 2011).

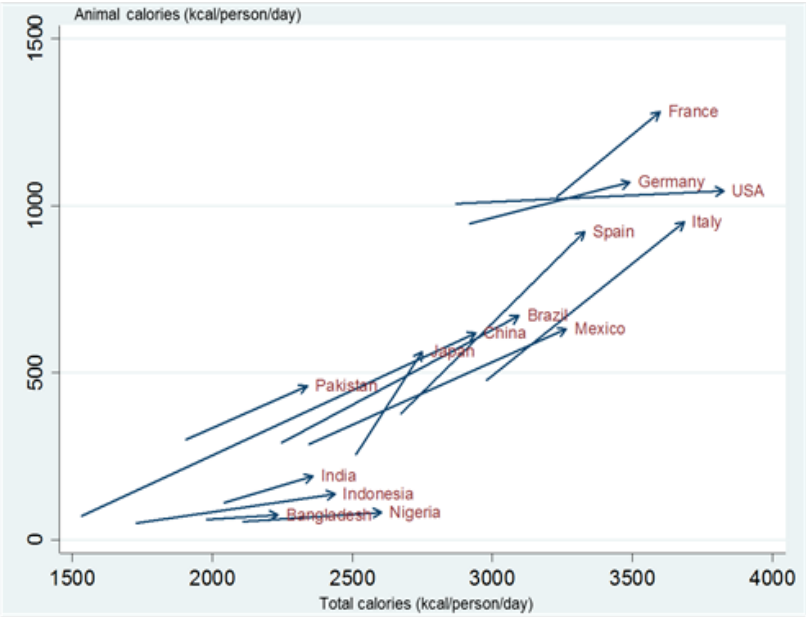


Figure 3

Evolution of total calories and calories from animal products (in kcal/person/day) in various developed, emerging and developing countries, 1961-63 to 2003-05. Source: Combris (2006) from the FAO Stat database

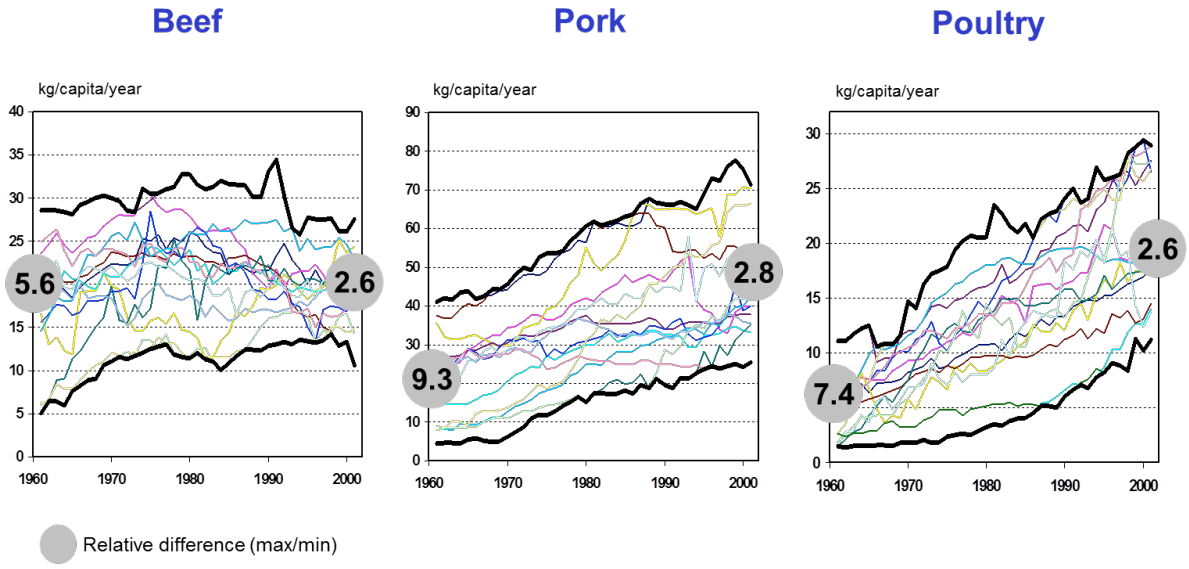


Figure 4
Beef, pork and poultry consumption in European countries (UE-15). Source: Combris (2006) from the FAO Stat database

2.2. Food products are increasingly transformed, sophisticated and ready-to-eat; also they are increasingly sold by supermarkets and eaten out of the home

The Westernization of food consumption patterns may not be characterised simply by the rise in calorie intake, the increase in sugar, fats and animal products and the simultaneous decline in cereals, potatoes and pulses. Food products are also increasingly transformed, sophisticated and ready-to-eat. In 1960, 80% of French food expenditure corresponded to transformed agricultural products (Etievant et al. 2010). Since that date, the share is practically stable (83% in 2006) but the nature of the products has considerably changed. Fresh refrigerated products are today 25 times higher than in 1960. Ready-to-eat products started to develop in the 1990s and today represent a significant share of food expenditure: for example, ready-to-eat products from fish were five times higher in 2000 than in 1960.

In a growing number of countries, unique traditional food habits and ethnic cuisine are increasingly replaced by prepared and ready-to-eat products, soft drinks, supermarkets and Westernized fast foods. In 1945, milk consumption in the United States was four times as high as that of carbonated soft drinks; 50 years later, Americans were drinking 2.5 times as much carbonated beverage as milk (Kearney 2010). The frequency of eating food prepared outside the home is also well documented for the United States, where the share grew from 26% in 1950 to 39% in 1995 (Swinburn et al. 2004). Supermarkets, along with large-scale food manufacturers, have profoundly transformed agri-food markets in developed countries over the 50 years from 1950 to the beginning of the 2000s (Reardon and Swinnen 2004). Similar changes have taken place in Central and Latin America in only one

decade, from 1990 to 2000: at that date, the share of supermarkets in the retail business in Mexico and South America (60%) was four times higher than in 1990 (Reardon et al. 2003). From 2000, the movement extended to Eastern and Central Europe, East and South-East Asia and many urban areas and countries in Africa.

2.3. Substantial food losses and waste at distribution and final consumption stages in countries where the diet transition is achieved or occurring

At global level, less than half of the calories produced by farmers ever make it onto the dinner table, as illustrated by Figure 5. In the early 2000s, farmers globally produced an average of 4,600 kilocalories per capita per day, including nearly 600 kilocalories lost at the time of harvesting or just after. At that stage, the percentages in losses were strikingly higher in developing countries compared to developed nations. The remaining 4,000 kilocalories were divided between animal feed (1,700 or 43%) and human food (2,300 or 57%). The 1,700 kilocalories used for animal feed produced in return 500 kilocalories in the form of eggs, dairy products or meat. Of the 2,800 kilocalories (2,300 from plant products and 500 from animal products) available for human consumption, another 800 kilocalories were lost through distribution and final consumption. At this stage, the percentages in losses were much higher in countries where the diet transition was achieved or occurring, than in the developing world. Finally, on average, of the 4,600 kilocalories produced from plant products for each inhabitant of the world, only 2,000 ended up for actual human consumption (Smil 2000).

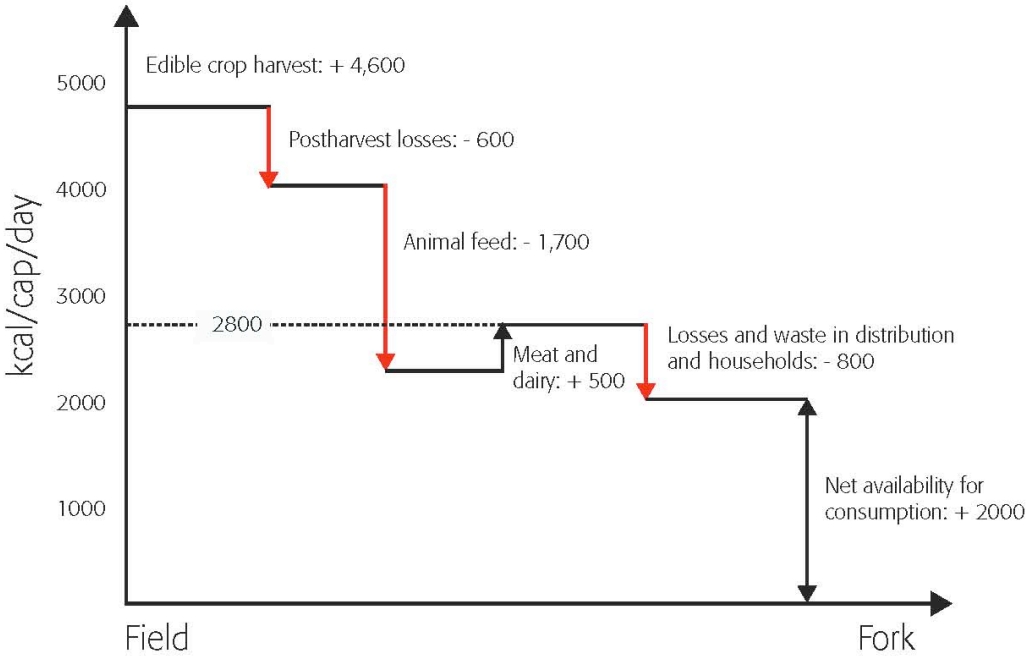


Figure 5
From field to fork: estimation of food losses, conversion and wastage in the world food chain.
Source: Lundqvist et al. (2008) from Smil (2000)

These figures show that reducing losses and waste, from field to plate, is a potentially powerful lever that can be used to increase world food availability and define more sustainable food systems and diets. These losses and waste correspond to both market (pecuniary) and non-market (environmental) costs. It is relatively easy to reduce post-harvesting losses, through efficient disease control and the development of infrastructure for storage, transport and marketing. At this level, it is essentially a matter of investment and thus of budget resources. It is much more difficult to reduce losses and waste at distribution and final consumption levels since this requires profound changes in food consumption patterns and possibly an easing of regulations (as long as food safety requirements are met). There is notably a data shortage on the amount, quality and causes of food waste and losses at the household level.

2.4. The gap between agricultural production, food consumption and consumers is widening

The Westernized food system is also based on reducing the range of primary agricultural commodities and achieving specialization for food manufacturers at two stages of the food chain, namely fractioning and formulating, in order to provide consumers with a growing variety of transformed products of regular quality. Traditional consumer skills required for selecting, preparing and storing food products are transferred to the transformation and retail stages of the food chain (Dubuisson-Quellier 2008). Consumers also have to accept that processors and retailers control food safety by conforming to public regulations and standards (Dubuisson-Quellier 2010). They need to quickly acquire new skills to face a rising range of transformed food products, in particular a better understanding of labelling and marketing information.

This evolution generates a 'technological' distance between consumers and agricultural products. More generally, the gap between agricultural production, products and producers on the one hand and food consumption, products and consumers on the other, covers the three dimensions of technology, space and time (Colleu et al. 2010). The length of the food chain is growing and food products are more and more sophisticated (technological gap); there is a growing disconnect between production and consumption zones (space gap); and the delay between agricultural harvest and food consumption is extending (time gap). As this three-dimensional gap widens, it makes the final consumer more demanding and anxious about the content and safety of her food (Soler et al. 2011). The most concerned households, usually well educated and rich, are increasingly seeking an answer to this anxiety through new ways of consumption (organic foods, local food systems) aimed at re-establishing a link between what consumers eat and where and how food is produced.

3. Consequences: increasing risks linked to the Westernization of food patterns

The consequences of food consumption patterns presented in Section 2 are now analysed in terms of risks, as risks require action, notably public action. The latter will be efficient if it modifies drivers of undesirable evolutions and changes. These drivers are discussed in Section 4.

3.1. Impacts on natural resources and the environment

The Westernization of agricultural and food systems has negative impacts on natural resources and the environment that are well documented in the literature. Simply put, impacts are related to the so-called intensification of agricultural practices and systems (effects at the intensive margin of production) and the increasing use of land for agriculture (effects at the extensive margin of production). Since the Westernization of food diets largely determines the evolution of agricultural practices and systems, as well as food and feed uses of land, eating patterns clearly have a responsibility for over-use and the degradation of agricultural ecosystems.

Much has been written about the negative impacts of the intensification of agriculture (food and feed crops, as well as grass) on natural resources and the environment (soil, water, biodiversity, etc.). Modern agriculture has been successful in increasing food production over recent decades but this has led to an environmental cost due to the use of high levels of water, fertilizers and pesticides, along with a reduced number of crop species and varieties being selected. This, in turn, has led to the depletion of aquifers, increased emissions of nitrates and pesticides into the atmosphere and biodiversity losses (see, for example, European Commission (2011) in the case of the European Union).

3.1.1. Biodiversity

Firbank et al. (2008) show that modern agriculture has a negative impact on biodiversity through three channels: i) the management of crops to increase their productivity through breeding, fertilizer use and the control of competitors, predators and parasites with pesticides; ii) the transformation of agricultural landscapes into new combinations and arrangements of crops and semi-natural elements; and iii) the transformation of non-agricultural and agricultural habitats. One of the main pressures on biodiversity is the transformation of natural habitats to agriculture, notably through forest clearance (Jenkins 2003). The negative impact of intensification on biodiversity is very well documented in the case of birds. For example, Chamberlain et al. (2000) show that the large shifts in agricultural management that occurred in England and Wales over the 1962-95 years are a plausible explanation for the decline in the farmland bird population observed over the same period. This decline involves many mechanisms among which are a reduced food supply for birds, less suitable nesting habitats and direct mortality of birds through farming operations.

3.1.2. Greenhouse gas emissions and climate change

Globally, agriculture, including direct and indirect land-use changes, accounts for one third of world greenhouse gas emissions (Figure 6). Agricultural greenhouse gas emissions (14%) come from three main sources: (i) nitrous oxide emissions essentially linked to the use of nitrogen fertilizers, (ii) methane emissions produced by ruminant animals through the enteric fermentation process or the anaerobic decomposition of manure, and (iii) carbon dioxide emissions from combustion of fossil fuel. The large rise in the use of nitrogen fertilizers, the number of beef and dairy animals, the number of livestock confinement systems and the agricultural use of fossil fuel have substantially increased agricultural greenhouse gas emissions over the last decades. Land-use change emissions (18%) result from the conversion of carbon rich habitats such as forests or permanent grasslands to

crop plantations and temporary grasslands for food, feed or fuel. These land-use change emissions, more specifically the indirect ones corresponding to the conversion of crops for producing biofuels that would otherwise be used for food or feed, are at the heart of the very complex debate on the sustainability of biofuels. But the question is not limited to biofuels. It also includes livestock and the rising consumption of animal products as a result of the Westernization of food diets. Expansion of grazing land for livestock is a key factor in deforestation, especially in the Amazon, where it is estimated that 70% of previously forested land is now used as pasture, and feed crops represent the main part of the remainder (FAO 2006). Globally, FAO estimates livestock production is responsible for 18% of world greenhouse gas emissions[1].

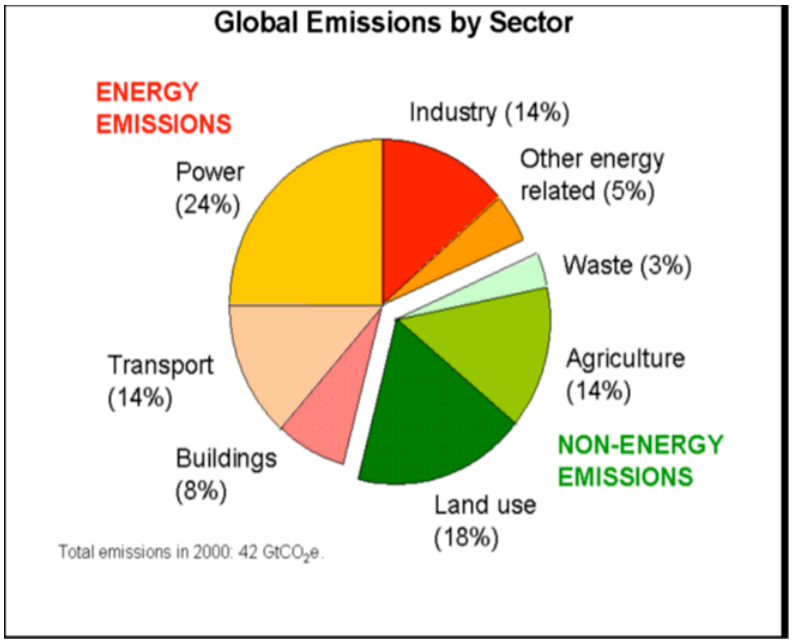


Figure 6
World greenhouse gas emissions by sector. Source: IPCC (2007)

3.1.3. The growing demand for animal products

In addition, as already discussed in Section 2, animals are less efficient than crops in transforming solar energy into calories. At a global level, of the 1,700 kilocalories per person, per day used for animal feed, animals return only 500, thus having a feed-to-animal-product conversion factor of 2.9.

[1] This estimate sums up emissions of the livestock commodity chain at the various production stages; they include deforestation for pasture and feed crops, animal production and the processing and transportation of animal products.

Conversion factors vary widely depending on the category of animals[2] as well as the production practices and systems used to produce the meat. Globally, poultry and pork production appears more efficient than ruminant animal production.

One essential characteristic of the food transition process is the increasing consumption of animal products, notably meat. Since very few countries can secure the corresponding additional protein demand by grazing, the solution lies in intensifying the cultivation of feed crops (mainly corn and soya), and expanding their cultivated area and/or their import. As a result, decreasing the global amount of animal production and consumption appears to be a potential lever for increasing global food security and the sustainability of the world agricultural and food system. However caveats exist.

Firstly, reducing the consumption of meat products is not advisable on health grounds for many households who lack protein in food diets. Furthermore, ageing people need a specific protein consumption to combat the decrease in protein metabolism efficiency; such proteins are present in animal products. Secondly animals, especially ruminants, present several advantages from a production point of view: they can exploit large herbaceous areas that would otherwise be unproductive; they provide organic fertilizers and work as draught animals; and they are an important source of income and assets. Finally, the global food equation must be kept in mind, as well as the roles vegetal and animal production play alongside other uses of land.

3.2. Impacts on nutrition and health

The diet transition summarized in Section 2 can equally be called the nutrition transition, as the changes observed in the nature of the food items consumed result in substantial changes in the percentages of the various macronutrients that compose the energy supply of the diet. The consumption of basic food products (cereals, pulses, starchy foods) declines while that of other food products (sugar, fats, animal products and to some extent fruit and vegetables) increases. This translates into a quick increase in the percentage of lipids in the diet - up to more than 40% in many developed and emerging countries and households - and a sharp decrease in the percentage of complex carbohydrates, starch and fibres. The percentage of proteins is more stable; however this apparent stability masks a switch from plant to animal protein sources.

This nutrition transition is associated with changes in lifestyle, such as growing urbanization[3], increasing sedentary activities, changing modes of transport, etc., resulting in a switch from high to low physical activity. The conjunction of inadequate situations in terms of nutrition, lifestyle and physical activity has been demonstrated to be associated with increasing risks of overweight, obesity and diet-related diseases (Shetty 2002[4]; WHO 2003).

[2] For example, in the United States, 2.6 kilogrammes of feed are needed to produce one kilogramme of chicken but 7 kilogrammes are needed to produce one kilogramme of beef meat (Leibtag 2008).

[3] See Satterthwaite et al. (2010) who specifically analyse urbanization and its consequences for food and farming.

[4] Shetty (2002) analyses the nutrition transition and its health consequences in India.

Overweight and obesity basically result from an imbalance between (increasing) calorie intake and (decreasing) physical expenditure. Table 1 illustrates the simultaneous rise in the calorie intake and the number of overweight and/or obese people in various developed countries between 1980 and 2005/2006. The problem is not specific to high-income countries. Overweight and obesity are dramatically rising in many Southern countries in connection with the nutrition transition occurring, especially in urban settings. Emerging countries are the most affected (Brazil, China, India, etc.) but several of the poorest countries of the world are implicated as well, with the exception, at least for the moment, of sub-Saharan Africa countries. In China, obesity levels among adults are today in excess of 20%; 90 million are obese and 200 million suffer from overweight (Popkin 2008). As the latter noticed, there are now more overweight and obese people in the world than underweight (Popkin 2006).

Table 1
Obesity, overweight and calorie intake in various developed countries, 1980 and 2005/2006. Source: Etile (2010).

Country	Obesity among adults (ratio in %)		Non obese but overweight adults (ratio in %)		Obese or overweight children 7-11 year old (ratio in %)	Calorie intake in kcal/day/person (In brackets, % of fat)	
Year	1980	2006	1980	2006	2000	1980	2005
Australia	8.3	18.7	28.0	34.4	26.2	3 051 (33 %)	3 084 (39.1 %)
Canada	13.8	23.1	35.4	36.1	25.1	2 946 (37 %)	3 552 (37.1 %)
France	6.5	11.5	26.9	31.5	19.0	3 376 (39 %)	3 603 (40.7 %)
Germany	na	13.6	na	36.0	16.0	3 338 (37 %)	3 510 (35.9 %)
Greece	na	16.4	na	41.3	31.0	3 216 (35 %)	3 700 (35.7 %)
Italy	7.1	10.2	27.4	35.0	36.0	3 589 (32 %)	3 685 (38.4 %)
Japan	2.0	3.4	15.6	21.8	17.8	2 720 (23 %)	2 743 (28.0 %)
Netherlands	5.1	11.3	28.2	35.2	12.0	3 071 (38 %)	3 240 (38.2 %)
Norway	na	9.0	na	34.0	18.5	3 350 (40%)	3 478 (37.4 %)
Great Britain	7,0	24.0	29.0	38.0	20.0	3 159 (39 %)	3 421 (36.5 %)
USA	15.0	34.3	32.4	33.0	15.2	3 155 (36 %)	3 855 (39.4 %)

Although there are methodological difficulties and constraints when assessing the long term consequences of eating patterns on health and population levels, it is now well known and proven that these changes in the diet composition have undesirable health effects, by increasing the risk and prevalence of type 2 diabetes, coronary heart disease, cancer, osteoarthritis, work disability and sleep apnoea (see, for example, Visscher and Seidell 2001).

Many low- and middle-income countries are increasingly facing a double burden of under-nutrition (deficiency in energy or micronutrients, or both) and infectious diseases on the one hand, and over-nutrition, overweight, obesity and degenerative diseases on the other (WHO 2011). This double burden is observed not only at country, but also at community or household levels. Children in low- and middle-income countries are more vulnerable to inadequate pre-natal, infant and young child nutrition. At the same time, they are exposed to high-fat, high-sugar, high-salt, energy-dense and

micronutrient-poor foods, which are often cheap. These dietary patterns, in conjunction with low levels of physical activity, result in sharp increases in childhood obesity while under-nutrition remains unsolved.

Overweight and obesity have a cost for society, both directly and indirectly, because of absenteeism and reduced productivity at work. Figure 7 illustrates this point for full-time employees in the United States: it clearly shows that medical expenditure and indirect costs due to absenteeism and lower productivity at work rise with the degree of overweight and obesity.

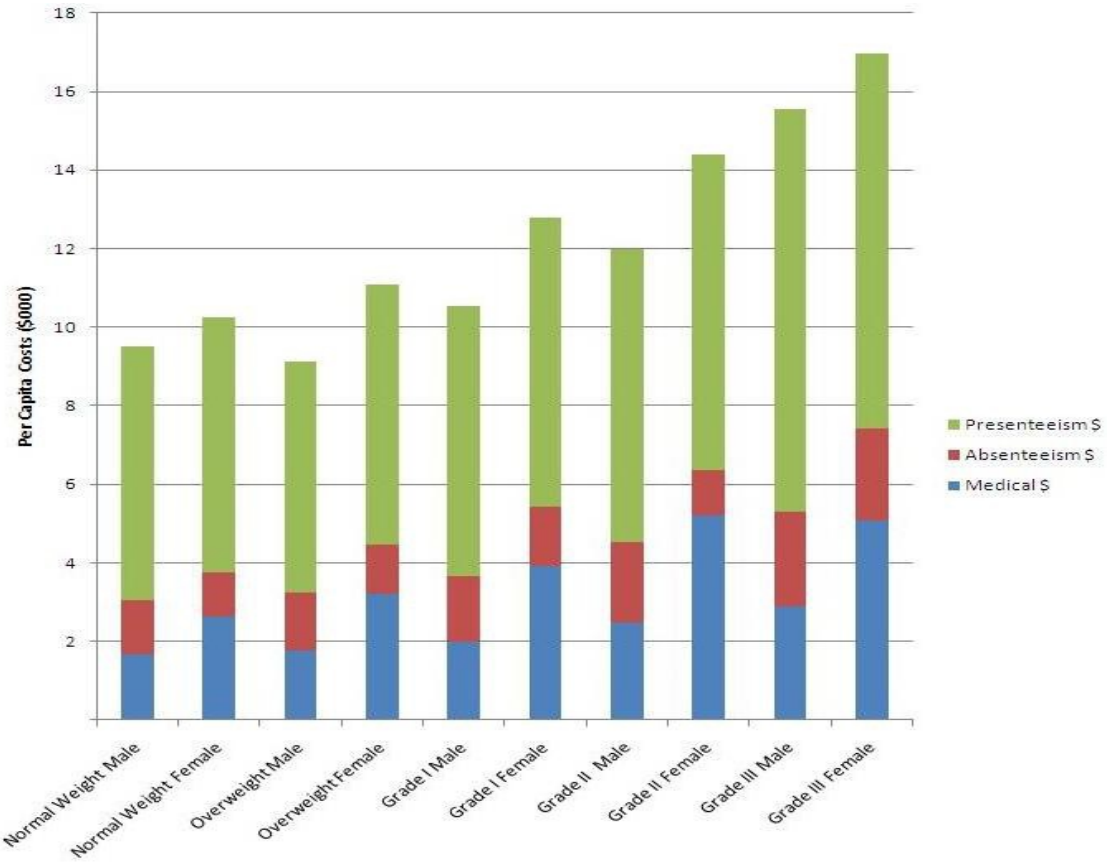


Figure 7
Direct (medical) and indirect costs due to overweight and obesity in the United States. Source: Finkelstein et al. (2010)

3.3. Things are not so simple: the relationship between the nutritional value of diets and their environmental impacts can be ambiguous

Analysis of sub-sections 3.1 and 3.2 demonstrates that the nutrition transition has negative impacts on both environment and health. At a global level, Stehfest et al. (2009) showed that a healthy diet would allow crop areas to be reduced by 10%, and grassland by as much as 10%, with a decrease in mitigation costs of carbon dioxin emissions by 50% (in 2050 relative to a reference scenario following FAO trend assumptions).

But are things really so simple or, in other words, is it so easy to define eating patterns that are preferable from both an environmental and nutritional point of view? A recent study performed by researchers from INRA and ADEME (Darmon and Soler 2011; Vieux et al. in press a) suggests it might not be the case. More specifically, the study concludes that nutritionally adequate self-selected diets may engender higher greenhouse gas emissions than nutritionally inadequate diets. This can occur because nutritionally adequate diets with reduced quantities of animal products are replaced by higher quantities of plant-based products to provide the necessary nutrient intake. This shift can generate high greenhouse gas emissions, perhaps even higher than the nutritional equivalent of animal products. For the same reason, Vieux et al. (in press b) suggest that replacing (red) meat by fruit and vegetables is not always the best (most efficient) option for reducing the greenhouse gas emissions of diets. In these studies, the most effective way of associating health and environment benefits appears to be a reduction in food quantities consumed.

4. Drivers of eating patterns

Food consumption depends on a large and complex set of factors related to food availability, accessibility and choice (Kearney 2010). In this section, we review the various determinants that shape the nutrition transition process. Some are specific to individuals and others depend on their environment. Some are physiological while others are linked to food characteristics, or find their root in social interactions and cultural background. Furthermore food behaviour is under the complex influence of a large range of short-, medium- and long-term regulation policies that involve these different drivers. Attention is focused on the underlying mechanisms of these drivers and their relative importance, in order to pinpoint levers that could be used to limit deregulation sources and favour sustainable regulation pathways. An overall approach to food and diet patterns is required.

4.1. Physiological factors

4.1.1. Nutritional requirements

The primary reason for eating is the necessity for each individual to meet her nutritional needs. Energy and specific nutrients are needed for body maintenance, as well as specific functions such as growth, pregnancy or lactation. Except during infancy where maternal milk can cover all nutritional requirements, eating a combination of different food products is necessary to ensure an adequate supply of all needed nutrients. There is an almost infinite variety of food combinations that can

define an adequate diet from a nutritional standpoint. This is an important consideration both from a cultural perspective and when considering food-based dietary guideline development.

Whereas biological events accounting for nutritional needs, such as cell and tissue metabolism, take place continuously over time, food intake is discontinuous in time and is organized around a few eating occasions on a daily basis.

4.1.2. Short- and long-term regulation of food consumption and metabolism

Food intake has a circadian variation, with food being ingested during activity periods (daytime for man) and fasting during the rest of time (rest and sleep periods). During the feeding period, food intake is discontinuous for most species. In the case of animals, the lag-time between two intake periods is a major factor of energy intake control. In the specific case of humans, the pace of feeding episodes is influenced by a complex range of social references that define the number and content of food intakes (that is meals).

Each eating occasion is made up of three components: first, the pre-ingestive phase where hunger can be experienced; this is followed by a prandial phase during which food is ingested, leading progressively to a feeling of satiation; and finally a post-prandial phase of variable duration corresponding to satiety.

Overall food intake is controlled by both the quantity of food ingested during eating episodes (involving the satiation process) and the time elapsed since the last eating episode (involving satiety controlled on a short-term basis). It also depends on food availability, which represents an environmental (external) control mechanism.

The main mechanisms controlling food intake are increasingly well known and understood. They include brain structures, mainly located in the hypothalamus (Woods and D'Alessio 2008), and regulation through signals, both short and long term (Berthoud 2007). Short-term signals are sensory and digestive and are thus directly linked to food intake. The nutritional composition and consistency of food determine the satiation capacity. The long-term regulation process involves hormonal signals, mainly leptin and ghrelin (Cowley et al. 2003). Their intensity is linked to adipose tissue mass with a delayed action as compared to the time of eating.

4.1.3. Food intake control by physiological mechanisms is disrupted by immediate environmental factors

The whole set of regulation mechanisms described above allows self-regulation of energy intake, being particularly effective in young children in 'normal' situations (Birch and Deysher 1986). This is not the case in obese people where this regulatory system seems to be altered (Blundell et al. 1993).

Energy compensation can take place between two successive meals in case of temporary deficiency or excess. But dietary deficiencies are compensated far more easily than excess is managed. In a society of food abundance and choice, temporary overeating is thus more likely to be poorly managed during subsequent meals, leading to excessive weight gain, overweight and obesity.

Food intake is adjusted more effectively by eaters who are 'listening' to the physiological signals of hunger or repletion and pay more attention to what they eat. Distractions (such as eating in front of the television or in a noisy place) increase the quantity ingested during the meal and upset the energy compensation process from one meal to the next (Bellisle et al. 2009).

Eating triggers a sensation of enjoyment by activating a physiological system in the brain called the reward circuit. Eating enjoyment is accentuated by palatable foods, which are often fatty or sweet, high energy-dense food items. A propensity for sweet foods has been observed from birth. In obese animals and humans, recent findings have shown that addictive-type mechanisms can develop for sweet foods.

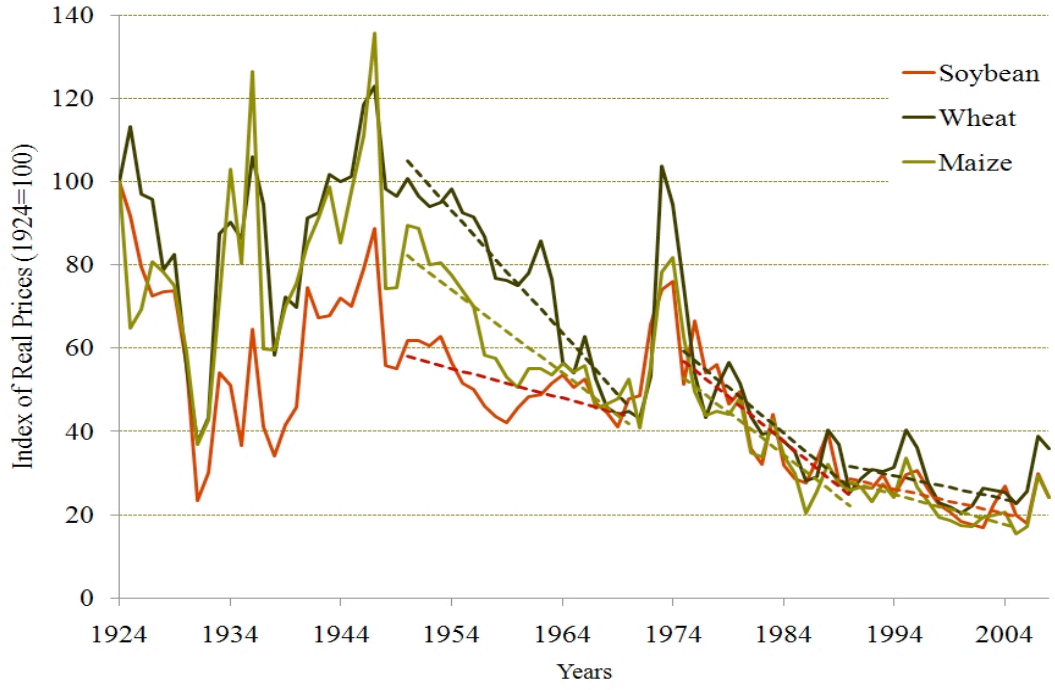
Social norms and attitudes, which vary according to age group, personal experience, social and cultural background, etc. shape and set dietary behaviour as regards time schedules, family meals and table manners. These social conventions also affect the physiological regulation mechanisms (Rogers 1999).

4.2. Economic factors

4.2.1. Food prices, more or less influenced by policies, notably agricultural policies, play an essential role

The industrial revolution (18th and 19th century) and then the agricultural green revolution have allowed world agricultural and food prices to decrease in real (deflated) terms over several decades. Over the past 50 years or more, the supply of most agricultural and food commodities has grown faster than the demand in spite of an increasing population. As a result, the real prices of agricultural and food commodities have trended downwards over many years. This is illustrated by Figure 8 which depicts United States price indexes for maize, wheat and soybean from 1924 to 2008, expressed in real terms by deflating the index of prices paid by farmers (Alston and Pardey 2009).

This declining price trend has contributed to the alleviation of hunger in the world in relative terms (that is, in percent, from more than 30% in the 1970s to slightly more than 15% today) and also in absolute numbers over the three decades 1970-2000 (but not from 2000, especially during the 2008 food crisis and the 2009 financial crisis). Lowered prices of calories have also contributed to easing the nutrition transition and accelerating it in non-developed countries.



Source: Compiled by the authors with data cited in Alston, Beddow and Pardey (2009b).

Notes: Nominal prices were deflated using the real farm price index. Dashed trendlines represent ordinary least squares regression lines of best fit where the respective commodity price was regressed against a linear time trend during each of the periods 1950-1970, 1975-1990, and 1990-2008.

Figure 8
US real prices of maize, wheat and soybean. Source: Alston and Pardey (2009)

Impact of food prices on eating patterns

Relative prices of agricultural and food prices can also influence the diet composition by favouring food items that are unhealthy from a nutritional point of view or, on the contrary, disadvantaging them. For instance, Beydoun at al. (2010) conclude that "food [relative] prices are associated with dietary quality, fast-food consumption and body mass index among US children and adolescents."[5] More specifically, they show that lower prices of fruit and vegetables are associated with greater fibre consumption and reduced body mass index; at the opposite end, higher fast-food prices are associated with lower consumption of fast foods and higher consumption of dietary fibres, dairy products, calcium and fruit and vegetables. Modifying relative prices of unhealthy *versus* healthy foods (by increasing the relative price of unhealthy foods vis-à-vis healthy foods) therefore appears to be a lever than can be used to improve dietary quality. From that perspective, more and more voices are raising the issue of a potential connection between agricultural policy and overweight and obesity: agricultural policy could keep the prices of the main crops artificially low (cereals, oilseeds

[5] Title of their article published in 2010 in the Journal of Nutrition.

and sugar crops), and thus do the same for the prices of processed food ingredients and the prices of animal products that use these crops as feed inputs, compared to less dense foods such as fruits and vegetables (Schaffer et al. 2007). For example, Schnoover (2006), quoted in Schaffer et al. (2007), argues that in the United States there is a direct relation between declining real prices for corn and soya, increasing use of fats and oils in processed food products and the rise in obesity, all of which would be directly related to each other. Similarly Lloyd-Williams et al. (2008) conclude that the Common Agricultural Policy of the European Union has led to a significant increase in cardiovascular mortality as it has favoured the consumption of saturated fats.

What responsibility for agricultural policy?

There is however a strong debate about the health effects of agricultural policy and whether new pricing and/or subsidizing rules in the agricultural sector could help individuals adopt better eating habits. Furthermore, as noted by Mazzochi et al. (2009), 'new' pricing and/or subsidising or taxing policies, while discussed regularly, are rarely enforced.

Price support policies and import trade barriers used, for example, in the European Union or the United States, have a positive impact on the domestic prices of commodities supported or protected in this way. As a result, they reduce their consumption, *ceteris paribus*. In contrast, coupled production subsidies tend to reduce domestic prices (because they invite farmers to produce more) and thus increase the consumption of products supported in this way, *ceteris paribus* again. Suppressing the whole set of agricultural policy instruments used in a given country may thus have an ambiguous effect on the caloric content of diets and their composition, depending on the relative importance of each instrument and how each agricultural product is supported or protected, as well as the distortion effect of each instrument. This is confirmed by the work of Alston et al. (2010) who show that eliminating all United States agricultural policies would have only a very modest impact on calorie consumption in that country: more specifically, eliminating grain subsidies would decrease annual caloric consumption by less than 1,000 calories for each American adult while eliminating both grain subsidies and trade barriers would increase this annual caloric consumption by around 200 calories for each American adult.

However, this does not mean that the lever of agricultural policy is neither relevant nor efficient for improving food diets. The problem is not with production subsidies, trade barriers or consumption taxes *per se*. It is rather with the disconnect between the current forms of farm programmes as they are applied in a vast majority of countries and the long-term policies that should be set up to promote healthier diets and more generally, the sustainable development of food systems, from field to fork. In other words, the problem is with the inconsistency of current (agricultural) policy, which very often neglects spill over effects. This can be illustrated by the work of Bonnet and Requillart (2010) who analyse the impact of the European sugar reform on the consumption of sugar sweetener beverages in the European Union. The reform mainly consists of a significant decrease in the domestic sugar price. It is aimed at gaining consistency (between policy instruments used in the sugar sector and in other agricultural sectors) and compatibility with World Trade Organization rules. But in doing so, the reform is at odds with what is recommended by nutritionists and public health authorities. Specifically Bonnet and Requillart (2010) show that the reform would raise the French consumption of regular soft drinks by more than one litre per person per year and the consumption

of added sugar by 124 grams per person per year. Furthermore, the substitution game between brands would favour products with the highest sugar content and the rise in consumption levels would be more significant in overweight and obese households.

4.2.2. Household incomes are a key determinant of eating patterns

It is now well established that rising household incomes lead to more unhealthy diets by favouring an increased consumption of fats, oils, sugar, animal-based products and processed foods (Périssé et al. 1969).

This causality should not invite us to blame an increase of individual incomes. As noted by Kearney (2010) quoting Marmot (2001), "in most industrial countries (for example, the United States or the United Kingdom), the effects of increased income have generally been considered as beneficial, resulting in better quality diets, better healthcare, lower morbidity and mortality from infectious diseases and lower risk of obesity." In developed countries where the nutritional transition is achieved and in emerging or developing countries where it is occurring, the conventional wisdom is that the poorest families have the worst diets from a nutritional standpoint. This is mainly because lower-income people have less access in their immediate neighbourhood to affordable healthy foods like fruit and vegetables that are relatively more expensive than high caloric foods. Relative to richer and more educated households who can largely choose their lifestyle, poorer and less educated families have fewer food choices. This shows that even if income is a key parameter, it cannot and should not be analysed independently of the whole set of food consumption drivers: these include food prices (see above) but also many individual variables such as socio-economic status, culture or religion, as well as environmental or global determinants like urbanization, globalization and marketing. This means that a systemic approach to food consumption behaviours is required; otherwise one risks coming to erroneous conclusions and making inefficient policy recommendations. This point can be illustrated by the study of Hawkins et al. (2008). They show that children from British families with an income between £22,000 and £33,000 are 10% more likely to be overweight or obese than those from families with an income of less than £11,000. This is mainly because of the rise of highly paid working mothers in the first group of families who are then forced to leave a nanny, child minder or similar, in charge of their children's diet and physical exercise. They conclude that "long hours of maternal employment, rather than lack of money, may impede young children's access to healthy foods and physical activity. Policies supporting work-life balance may help parents to reduce potential barriers."

4.3. Other important drivers: urbanization, food retailing and industry, marketing and advertising, food environment, sociology and culture

4.3.1. Urbanization

Historically urbanization is strongly related to industrial and agricultural revolutions. A decline in physical activity results in lower energy needs, while at the same time working ability, life span and life quality increase. Today the challenge consists of feeding an increasingly urbanized world population and a growing number of very large megacities (especially in emerging and developing countries) in a sustainable way, while improving the situation of farming and rural households who

still represent the bulk of poor and hungry people. The more a society is urbanized, the more it challenges the sustainability of its agricultural and food system, mainly in terms of transport, supply chain and modified diets.

The influence of urbanization on eating patterns is partly linked to the distance between consumers and the various supply sources: shops, restaurants, dispensers, etc. (Popkin et al. 2005). In the framework of the food transition process in developed countries, the number of supply sources, their relative importance and their repartition have undergone important changes in the last 50 years. In the United States for example, the concentration of fast-food restaurants accounts for the frequency of overweight and obesity cases (Inagami et al. 2009). Evolutions are now similar and, in addition, faster in a growing number of emerging and developing countries.

4.3.2. Food retailing and industry

In most developed countries, food supply has gone from specialized shops to larger and non-specialized supermarkets and shopping malls. In France, it took 40 years for this change to occur: while supermarkets and shopping malls were only 5% of total food expenditure in 1970, they now represent 70%. A similar evolution is occurring in many emerging and developing countries where uniform and centralized supermarkets and shopping malls are increasingly (and quickly) replacing small shops. The movement starts from basic foods like corn, oil or sugar, and extends to fresh ones. In emerging and developing countries, supermarkets and shopping malls are no longer the domain of the richer households of capital cities. They are now consumption places for urban crowds with increasingly Westernized lifestyles (Reardon et al. 2003).

The worldwide rise of supermarkets and shopping malls comes with the development of transnational food corporations (franchises and manufacturers) like Danone, Nestlé or McDonalds. These transnational food corporations are significant drivers of the nutritional transition and the Westernization of food consumption behaviours (Hawkes 2005, Kearney 2010). The “fast-food cultural infiltration” means that fast-food restaurants can be found in shopping malls, railway stations, airports, schools, etc. In highly populated communities, you can drive just a few kilometres and pass several fast food restaurants and convenience stores. The increase in these stores comes with the development and concentration of brand names that have changed the relationship between consumers and producers and led to changes in profit sharing along the food supply chain (to the detriment of agricultural producers).

4.3.3. Declining physical activity and growing food marketing

Many activities now widely undertaken by adults and children involve very little physical activity. In a growing number of cultures, the most popular leisure activities, especially in the case of children and teenagers, are watching television or videos, playing electronic or computer games, and surfing the internet. These passive forms of entertainment are replacing more traditional and physical recreational activities. This ever-increasing sedentary lifestyle is accompanied by growing marketing and advertising expenditures from both transnational food corporations and supermarkets - essential factors for the Westernization of food diets. According to Willett (2002), quoted in Kearney (2010),

exposure to TV advertising might even be the single largest determinant of child obesity in the United States.

4.3.4. Food environment, sociology and culture

People make decisions based on their food environment, community, family, culture, history, etc. All these miscellaneous factors influence food consumption behaviours and habits in a way that may or may not be favourable to more healthy diets. It is, for example, particularly important to create food environments that make it easier to choose healthy diets and engage in physical activity, especially by providing food options that are low in calories, fats and added sugar and rich in fruit and vegetables. In France, the convergence of eating patterns meets resistance from familial and cultural habits. In 1997, four out of five French people were having lunch at home on weekdays, a percentage increasing to 90% for dinner (Volatier 1999). Recent observations suggest that the first percentage is slightly decreasing while the second remains constant. Today 75% of French people have lunch at home but with considerable variation according to age, location and socio-economic status.

A common wisdom is that traditional meals are losing ground in France. Such an assertion is quite difficult to prove and feeds a controversy around "the breakdown of the French meal pattern". Sociology research shows that many factors interact around the French meal pattern, such as deregulation of family life, more individualized lifestyles and more independent, younger teenagers (Chauffaut 2001). Such evolutions could foster more individualized food intakes as illustrated by meal-trays used in front of the television, in sitting rooms or even with guests.

It also should be borne in mind that despite the global convergence of eating patterns throughout the world, several types of behaviours co-exist inside one 'pattern'. Nutritional implications of such disparities are expressed through social differences of health. Many diet-related diseases affect lower social categories more frequently and social inequalities in health are growing (Guignon et al. 2010; Mackenbach et al. 2008; Charles et al. 2008; Leclerc et al. 2006).

To reduce those inequalities, the study of main consumption trends should take account of various balances depending on life standards. Thus in France, the relative shares of animal and vegetal foodstuffs are known to vary according to income, education level and socio-economic status, the consumption of animal foodstuffs being lower in upper social categories (Caillavet et al. 2009; Recours and Hebel 2006). Similarly, nutritional messages are known to have different impacts depending on education level and social background (Regnier 2009).

5. Achieving greater sustainability of agricultural and food systems through healthier eating behaviours: action recommendations and knowledge gaps

As highlighted by the foresight exercise Agrimonde (Paillard et al. 2010), defining healthier and environmentally-friendly food diets would require changing behaviours along the whole supply chain, from consumption habits to agricultural practices and systems. Apart from the adjustment of

quantities consumed in relation to a better nutritional balance of diets, reducing losses and waste, as well as saving fossil and natural resources, are major targets.

5.1. Reducing food losses and waste along the whole food chain

FAO estimates that achieving global quantitative food security by 2050 would require an increase in world agricultural production by as much as 70% (FAO 2010). As established in the recent United Kingdom foresight on food and farming (2011), halving losses and waste along the food chain represents an economy of 25% of current agricultural production. Other estimates are even more optimistic. Harvest and post-harvest losses (the so-called primary losses) are much more important in the developing world, while losses at distribution and final consumption stages (also called secondary losses) are greater in developed countries, more generally in countries that experienced or are experiencing the food transition.

Factors for secondary food losses are multiple and involve a large set of complex mechanisms. They depend on exogenous factors (climate, safety, etc.) as well as human factors, including management practices. For example, the different actors and stages in the food chain, such as producers and market regulations (for example, withdrawals of fruits and vegetables because of quality standards), the food industry (in relation to issues such as supply chain management, packaging, safety rules and the recycling of wasted quantities), the retailing stage (where storage conditions and marketing are key parameters), and the final consumer, through the mechanisms which define her food consumption behaviour (see Section 4). These secondary food losses could be reduced by increasing their use in human food, by using them for animal feed, and by recycling, especially for energy production.

5.1.1. Improving the valorisation of raw materials

Priority should be given to the use of agricultural products for food. Extending and diversifying preservative processes can be used to delay the consumption of highly perishable products such as fruit and vegetables. Recycling technologies of co-products are efficient and well developed. For example, the content of milk proteins can be fully valorised though traditional outlets like cheese and simultaneously, thanks to membrane technologies, the residual whey proteins can be used as food additives in a very large range of products. It is not only a technological issue. In parallel, public policies should be developed for facilitating a reduction in losses and improving the food valorisation of raw materials. Education of all actors in the food chain, from producers to final consumers, is a key parameter for the long term. It could be efficiently supplemented by shorter-term regulation on prices.

A large part of world crop production is used for animal feed. Farm and company animals also use an extensive variety of co-products of first and second transformation agricultural products, notably oilcakes (from oilseeds), corn gluten feed and corn germ meal (from corn). As highlighted by UNEP (2009), valorising organic waste for feeding animals is a promising solution that would allow a significant decline in the tension on arable lands.

5.1.2. Developing new processes

As the carbon circular economy develops, biorefineries play a central role since they use plants and organic waste from both industrial and domestic processes (Colonna et al. 2011). Biorefineries go beyond processes currently used in the food industry, as they include renewable energy and green chemistry to optimise whole plant use. Based on improvements in production and recycling technologies, they are promising tools to reduce food losses and waste through a reorganization and management of resource use and recycling, and an increased valorisation of co-products. Perspectives offered by white and green biotechnologies are enlarging the range of valorisation possibilities thanks to the degradation of lignocellulose and the development of new sources of oils, solvents or biomaterials.

5.1.3. Understanding and changing domestic food practices

According to Redlingshöfer and Soyeux (2011), food losses and waste at home represent 42% of total secondary losses and waste in the European Union (89 million tons per year, i.e., 179 kilogrammes per person); the food industry comes second (39%, but including by-products that are generally well used), catering third (14%) and retailing fourth (5%). As a consequence, reducing food losses and waste at home is a potentially powerful lever. To achieve this objective and more generally to improve food management at home, a number of simple actions are available. For example, on her famous blog ("No More Dirty Looks"), Siobhan O'Connor presents 10 ways to reduce the food that American households throw out, and what to do with it if it really is past its prime[6]. Solutions include "store food properly", "make juice" or "cook then freeze" but also "find places that will make use of your waste" or "shop like a Parisian"[7]. More generally, this list of intuitive recommendations shows that changing individual food practices is difficult as far as the food environment is also concerned (not everyone can shop like a Parisian!).

The use of food at home as well as the sociological representation of what food means may be very different from one country to another, even those at the same development stage. It is also by changing the food environment and retailing and food industry practices, (especially in terms of advertising, labelling, marketing or packaging), and influencing public policies and education that it will be possible to significantly reduce food losses and waste at home, and along the whole food chain. Efficiency requires combining a large variety of actions that involve all actors in the food chain.

5.2. Defining and adopting healthier and more sustainable food diets

Westernized diets are unhealthy because of an excessive caloric intake or because they are unbalanced from a nutritional standpoint. Defining healthy and sustainable food diets is a challenge. Defining the conditions allowing people to adopt them is even more difficult. As in the case of food

[6] http://www.good.is/post/10-ways-to-reduce-food-waste-at-home/.

[7] This means having only the basics at home and going down to the neighbourhood grocery store before supper.

losses and waste (see above), there is no unique solution that could apply to all individuals and households in all countries. Combined actions playing simultaneously on demand and supply factors will be more efficient.

5.2.1. Assessing simultaneously the nutritional and environmental impacts of food diets

Assessing the nutritional and environmental impacts of different food diets is imperative. To that end, a research effort is required to develop methods aimed at assessing the nutritional value of food products and their integration in eating patterns. Related to that, good research at a sufficiently detailed level is needed on the nutritional qualities of plant and animal products; for example, restricting the consumption of animal products without adverse effects on health. Research should also target methods for assessing the environmental impacts of diets. To a large extent, research work developed in that domain concerns carbon dioxide and greenhouse gas emissions. Such research should be extended to other environmental dimensions, notably by including the impact of diets on fossil energy, water and biodiversity. Furthermore the definition of the carbon footprint of diets should take account of greenhouse gas emissions linked to possible and potential land-use changes. Research efforts currently developed in that domain are mainly applied to biofuels; they could, relatively easily, be transposed to food diets.

Such a research agenda implies a substantial effort in terms of methods and data, both of which should be coordinated and harmonized at an international level. Existing databases should be shared and extended, notably by incorporating information from the private food sector on processed products.

5.2.2. Reducing the quantities

As previously underlined in Sections 3 and 4, the challenge of reducing the intake quantity of over-nourished people is essential. It implies not only a modification of consumer habits but also a modification of the economic model of the supply chain, as the main driver for its development is currently an increase in quantities sold. Research is needed for developing new supply chain economic models, assessing their sustainability performances and working out how they could be implemented.

5.2.3. Better understanding of food consumption behaviours and their determinants to favour desirable changes

There is no single diet that can be considered as nutritionally adequate. Several diets can achieve the same nutritional requirements in terms of energy and specific nutrients. Even if detailed information is largely lacking for the moment (see above), these various diets, while adequate from a nutritional point of view, will very likely have differentiated impacts on the environment. But it is also very likely that there is no unique diet that is preferable from both a nutritional and environmental standpoint when all the environmental dimensions are taken into account.

Combined actions on demand and supply factors

Changing food consumption behaviours is a very difficult task as eating encompasses a large range of dimensions including historical, cultural, sociological and even emotional aspects. Changing food consumption behaviours requires mobilising simultaneously the various levers identified above (see Section 4) through a combination of actions affecting both the demand and supply side. An increasing number of success stories in different countries confirm that it is through a combination of actions that it will be possible to efficiently and durably change food consumption behaviours. These actions should comprise both short-term objectives and long-term targets.

Enhancing food intake control

Research in progress allows better identification of food properties (nutrient content, texture, sensorial properties, etc.) that have an impact on satiety/satiation as important biological events controlling food intake. Nevertheless, it is necessary to establish to what extent these are key effects for the control of body weight and composition. Furthermore, given the importance of the food consumption environment, it is crucial to act simultaneously on these environmental factors to induce sustainable food-related behaviour changes. Research and experiments should be conducted to identify the best ways to act on these proximate environment drivers. Public policy could then have an impact on public catering environments, lowering disturbance factors like noise, short eating times, etc. As for home conditions, consistent information should be given out regarding disturbance factors, like watching television while eating.

Acting on (relative) prices on foods

Modifying the (relative) prices of the different food products by taxing the 'bad' foods and subsidizing the 'good' ones is part of the solution, even if the distinction between what is a 'bad' and 'good' food is not simple, from both nutritional and environmental points of view. It is very likely however, that public policies that have either a direct or indirect impact on eating patterns, and more generally on food and agricultural systems, are insufficiently consistent. Thus, improving the consistency of public policies is a priority. This could be achieved by following two basic economic policy principles: first, to obtain a consensus (or at least a politically acceptable compromise) on policy objectives taking into account priorities and trade-offs; second, to target the objective at the source using a distinct instrument for each objective (following the so-called targeting principle) (this is because killing two birds with only one stone is most often inefficient). Furthermore, modifying the (relative) prices of the various foods would also influence supply by reducing the availability of more expensive goods (their prices should then go up) and increasing the availability of less expensive goods (their prices should then decrease).

Taking into account the specificities of individuals, social groups, countries, etc.

The efficiency of economic instruments will be enhanced if they are used in conjunction with other actions aimed at defining a better food environment and/or modifying behaviour habits, by targeting individuals, their families and their social communities. As there are critical periods for changing eating patterns during the life span, such as childhood, marriage, child birth or ageing (Etievant et al. 2010; Combris et al. 2011), efficiency will be gained by targeting those periods and taking into account the specific characteristics and needs of corresponding populations. More generally, as there

is a range of consumer types in each country and consumption behaviour varies during a consumer's life cycle, the research and policy agenda should address detailed knowledge of food consumption behaviours in relation to its position in the life cycle, socio-economic status and the food environment. This agenda includes, for example, the importance of job-related physical activity in explaining weight gaps; gender differences in food consumption, behaviour and weight; the role of the matching market, such as marriage or a birth, in determining behaviour and weight; or on a more global scale, the analysis of factors that contribute to maintaining differences in food consumption behaviour between countries, other factors being maintained or controlled (Philipson 2001).

Acting on demand factors

In a general way, action requires a better understanding of the multifactorial relationship of consumers vis-à-vis their food, how this relationship evolves and drivers of changes. Action should aim to better inform consumers on the risks of unhealthy food diets, overweight and obesity in the long term. It should also try to change food consumption behaviours through nutritional education, sensorial education (especially in the case of children and teenagers), social marketing (not only because this technique can modify individual behaviours but also social norms[8]) as well as clear and understandable food labelling (nutritional and environmental labelling). Efficiency will be enhanced if all these actions are combined and short-term measures are consistently included in a long-term action plan.

Acting on supply factors

In a large majority of cases, acting solely on the demand side is not sufficient. It is equally important to intervene on the supply side, more specifically in the food industry, the retailing sector and the consumption environment. In that regard, many analyses suggest that the free market is not optimal (see, for example, Hawkes 2007; Harris et al. 2009: Stanley and Daube 2009). Policy intervention is thus required and justified from a public economic point of view. Instruments that public authorities can use for that end are multiple, from simple interdictions to operations developed jointly with food industry and retailing actors. These should be encouraged as their efficiency in enhanced by the adhesion of actors to programme objectives. The research and policy agenda should also address the issue of food marketing and its regulation (see, for example, Harris et al. 2009), and the question of the 'architecture' of food choices (by decreasing the availability and visibility of unhealthy foods and conversely, increasing the availability and visibility of healthier options). This availability/visibility issue concerns not just shopping malls, fast-food restaurants and supermarkets, but also all buying and consumption collective places such as schools, canteens and work places. Several success stories in that domain are well documented (see, for example, Seymour et al. 2004; Knai et al. 2006; Laurence et al. 2007).

[8] See Kotler and Amstrong (2005); Henley and Raffin (forthcoming).

5.3. Saving fossil energy and natural resources

Reducing losses and waste along the food chain should permit the saving of fossil energy and other natural resources. In general, increasing the sustainability of eating patterns and food systems requires a decrease in the use of fossil energy and natural resources, notably water and land. Research needs and policy recommendations are illustrated here in the case of energy; they largely extend to water and land.

A recent report (Canning et al. 2010) summarizes the issue very well in the specific case of the United States, but the analysis extends to all countries with Westernized eating patterns and food systems. "Energy is used throughout the United States food supply chain, from the manufacture and application of agricultural inputs, such as fertilizers and irrigation, through crop and livestock production, processing, and packaging; distribution services, such as shipping and cold storage; the running of refrigeration, preparation, and disposal equipment in food retailing and foodservice establishments; and in home kitchens. Dependence on energy throughout the food chain raises concerns about the impact of high or volatile energy prices on the price of food[9], as well as about domestic food security and the Nation's reliance on imported energy. Use of energy in the food chain could also have environmental impacts, such as through carbon dioxide emissions." (Canning et al. 2010, page iii).

In the United Kingdom, the food system represents 13% of total energy consumption. Figure 9 breaks this percentage down by activities, from field to fork. It shows that transportation and logistics are highest (30%), followed by processing (17%) and catering (16%). This figure also highlights the small contribution of agriculture, with only 5%, while food cooking at home represents 9%. Figure 10 provides similar information for the United States. In that country, food activities at home come first with 31% and agriculture second with 22%, a percentage much higher than in the United Kingdom. Differences in category definition and data can explain the *a priori* surprising gap between the situation in the United Kingdom and in the United States[10]. More generally, this simple comparison suggests that the research agenda should address data needs to ensure that such breakdowns are robust and comparable. It should also address the detailed analysis of differences between countries and factors that could explain these differences, especially identifying and generalising the best practices. Here, a holistic approach is also required.

Energy use in food transforming activities is of the same order of magnitude in both the United Kingdom (17%) and the United States (16%). Following the energy crisis of the 1970s, the food industry developed and adopted new technologies to reduce its dependence on energy. Significant progress in the thermal processing of foods (multistage unit operations, energy recycling, notably by using co-products of the first transformation in the second one, replacement of non-thermal

[9] On the relationship between energy (crude oil) and agricultural / food prices, and the impact of this relation on agricultural / food price volatility, see Hajkowicz et al. (2011).

[10] Figure 10 and 11 are thus not directly comparable. In the case of the United Kingdom, energy consumption by agriculture does not include energy consumption of imported agricultural products. In the same way, the category "food cooking at home" retained in the United Kingdom does not correspond to the category "home activities" used in the United States.

technologies) has been achieved. Less research effort has been devoted to home food activities and the energy yields of culinary cooking techniques are far from being optimized. As a result, a priority of the research agenda is the question of home food management, including an analysis of losses, waste and energy consumption in culinary processes. Transport and energy use for that purpose are also of importance, notably because of the increasing distance between production and consumption places, as well as the concentration of food retailing (on this point, see Gaigné et al. 2011).

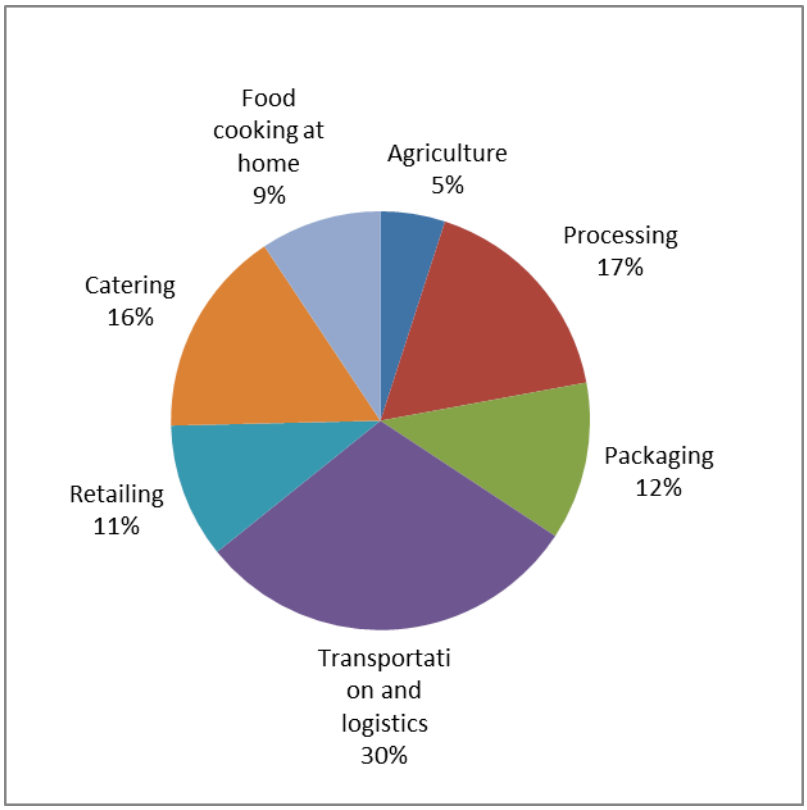


Figure 9
Breakdown of energy consumption of the UK food chain according to activities (2002). Source: Smith et al. (2005)

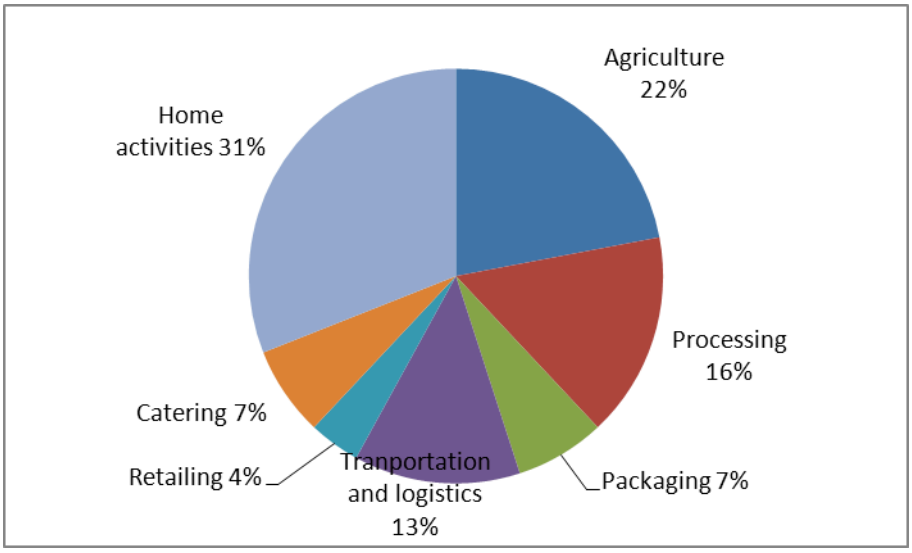


Figure 10
Breakdown of energy consumption of the US food chain according to activities (2002). Source: Heller and Keoleian (2000)

6. Conclusion

Acting on eating patterns is a key condition for ensuring global food security in the future, as there is a strong tie between food production and consumption. According to the foresight study Agrimonde (Paillard et al. 2010), if daily food consumption per person keeps steadily increasing, it will reach 3,600 kilocalories in 2050 and the world will have to produce no less than 62 G kilocalories for feeding nine billion people at that date (scenario “Agrimonde GO”); but if daily food consumption per person remains limited to 3,000 kilocalories in 2050, only 42 G kilocalories will need to be produced to achieve this goal - that is 32% less (scenario “Agrimonde 1”).

Ensuring global food security does not mean setting up a common eating pattern for every part of mankind: although they undoubtedly have tended to converge over the past decades, eating patterns remain diverse throughout the world, determined by a complex set of physiological, economic, historical, cultural and sociological factors. From that perspective, the Westernization of eating patterns is not suitable for every part of the world because of its numerous shortcomings and drawbacks, especially in terms of health and environment.

A holistic approach is needed to make eating patterns more sustainable and healthy. To do this involves first reducing losses and waste along the whole food chain. Such a reduction should result in significant savings of fossil energy and other natural resources, and those savings are a key condition to increasing the sustainability of both eating patterns and food systems. In fact, eating patterns and food systems can be sustainable if they rely on a thrifty use of fossil energy and of resources such as land and water. Setting up such systems must be a priority on the worldwide research agenda. Lastly,

food security can be ensured thanks to healthier and more sustainable food diets. This objective requires assessing the impacts of food diets, both nutritionally and environmentally. Far from being imposed, more sustainable diets must be based on changes accepted by everyone. This means a better understanding of food consumption behaviours and of their various determinants, so as to favour desirable changes through actions on demand and supply factors, and also on the relative prices of foodstuffs. These actions, of course, will have to take the specificities of individuals, social groups and countries into consideration.

Many actions need to be taken to ensure food security throughout the world. And many of those actions have something to do with eating patterns. In other words, when it comes to food security nothing can be carried out if eating patterns are not taken into consideration. Here is food… for thought!

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