Natural resource use for food
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Food consumption and economic development, a spatial and temporal comparison*

Abstract The coming decades will bring enormous challenges concerning food security. The current growth of the world population requires the production of more food. Along with population growth, many countries have shown increased purchasing power causing a demand for more and other food. Studies on human nutrition have shown that throughout the world a nutrition transition is taking place in which people shift towards more affluent food consumption patterns. Especially in Asia, average per capita food supply increases, accompanied by shifts towards the consumption of more meat and oil, and a decrease of the consumption of staples. The objective of this chapter was to analyze the relationship between per capita income (GDP), and food supply, the composition of food consumption, as well as the contribution of animal foods. It made a spatial comparison of food consumption patterns of countries in various stages of economic development for the year 2001. Additionally, the chapter made two temporal comparisons, a three century time trend for western Europe, and a forty year trend for southern Europe. The spatial and temporal comparisons showed the same patterns of change. For low incomes, an increase of GDP per capita paralleled changes towards the food consumption patterns of western countries, characterized by a large gap between supply and actual consumption. Total supply (kilocalories per capita per day) differed by a factor of two between low and high GDP. A second characteristic of changes of consumption was an exchange of the fraction of nutritional energy from carbohydrates to fats and to animal foods, while the protein fraction was stable. People with low GDP derived nutritional energy mainly from carbohydrates. The contribution of fats to nutritional energy was small, of protein the same as for high GDP, and that of animal sources negligible. People with high GDP derived nutritional energy mainly from carbohydrates and fats, the contribution of animal sources was substantial. Whenever and wherever GDP increased, food supply, the composition of consumption, and the contribution of animal foods all moved in the same direction. The fastest changes occurred in the lowest income categories, below 5000 1990 International Geary-Khamis dollars. The transition is completed at an annual, per capita income level of about 12 500 dollars. These findings have important consequences for food security. The European transition occurred in a gradual way enabling agriculture and trade to keep pace with the growth of demand. A continuation of present economic trends might cause a large pressure on the food system within ten years because changes in food demand occur much faster than projections indicate. Especially economic development in Asia will cause additional pressure on the global food system.

6.1 Introduction

Today, the need to supply sufficient food for the growing world population is an important issue (Pinstrup-Andersen, 2000). One of the principle aims of the United Nations Millennium Development

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goals, for example, is to eradicate hunger in the period 1990-2015 (United Nations, 2005). However, there is a difference between the supply of sufficient food and the consumption of food to prevent hunger. Supply is defined here as the average, annual, per capita availability of food commodities in a country. Many food commodities are basic ingredients for foods and have to pass chains and webs of a production system before they are available for consumption. In this system, several processes take place, such as, for example, processing sugar beet to manufacture sugar, or baking cakes (Gerbens-Leenes et al., 2003). The output of a food production system is the large quantity of food items available for consumption. Food consumption is defined here on two levels of scale, the household level and the per capita level. Household consumption concerns the foods available for a household, per capita consumption concerns the food that is actually eaten. In general, there is a gap between supply and actual consumption because in food production systems, as well as in households, losses occur.

Food consumption shows repeated arrangements referred to as food consumption patterns (Gerbens-Leenes and Nonhebel, 2002). These patterns depend, among other things, on household income. When income increases, people spend more money on food (Pindyck and Rubinfeld, 2005; Vringer and Blok, 1995) and in this way change their food consumption. Income expressed as average, per capita Gross Domestic Product (GDP) differs among countries and in time (Maddison, 2003). In the period 1700-2000, for example, western Europe showed a twenty fold increase of GDP per capita; in the period 1961-2001, southern Europe observed a three to four fold increase. At the same time, food supply increased substantially (Fogel and Helmchen, 2002; FAO, 2004a) and food consumption patterns shifted towards patterns including more affluent foods such as meat, fats, beverages, and fruits, in combination with a declining consumption of staples (Whitney and Rolfes, 1999; Smil, 2002; Gerbens-Leenes and Nonhebel, 2002; Jobse-van Putten, 1995; Receveur et al., 1997; Mennell et al., 1992; Penning de Vries et al., 1995). These shifts cause changes in the composition of food consumed and related food supply.

Today, the main differences among GDP per capita, food supply, and food consumption occur between developing and developed countries. GDP per capita in developing countries is low (Maddison, 2003) and food supply and consumption are mainly based on staples (FAO, 2003a). Developed countries show high GDP per capita, large supply and affluent food consumption patterns (Gerbens-Leenes and Nonhebel, 2002). However, studies on food consumption patterns in developing countries have reported shifts towards the affluent patterns of the western world (Grigg, 1995; Popkin, 2002; Lang, 2002; FAO, 2003a). The production of food requires natural resources such as agricultural land, water, and energy. More affluent food consumption patterns have larger requirements for these natural resources than patterns based on staples. Chapter 3, for example, has shown that a consumption pattern based on staples requires six times less land than an affluent pattern that includes large amounts of fats, beverages, and foods from animal sources, such as milk, cheese, and meat. In the next ten years, some developing countries will show large economic growth (World Bank, 2005b) and thus an increase of GDP per capita. Since the pressure on resources is already large, there is a need to quantify shifts in per capita food supply, and changes of consumption towards more affluent food consumption patterns that go along with an increase of GDP per capita. The specific aims of this chapter were twofold. First, to identify and analyze trends in per capita food supply and consumption that go along with increasing income (GDP per capita). The chapter quantified the gap between average, daily per capita food supply and actual consumption, shifts in the composition of food consumption, and shifts in the contribution of animal foods to consumption. Second, it identified regions where large changes in food supply and consumption will occur in the next ten years.

The paper is organized as follows. Firstly, Section I assessed spatial differences among food supply and consumption. Uncertainty and inaccuracy, however, go along with attempts to make an accurate analysis of a complex system, such as the food system. To assess the sensitivity of the spatial comparison and to confirm trends, the chapter made four additional analyses. Section II evaluated the probability of missing substantial food sources. To confirm trends found in Section I, Section III made a temporal comparison for western Europe.

### 6.2 Food systems

Food systems include a production and a consumption system. Figure 6.1 shows a simplified overview of the system. A production system consists of (i) agricultural production made up of primary and secondary production that provide a supply of crop and animal commodities, (ii) the food industry that applies the supply from primary and secondary production to manufacture food items for...
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Food consumption, and (iii) retailing. A consumption system consists of (i) household consumption defined here as types and amounts of food bought or produced by a household and (ii) per capita consumption that concerns the food that is actually eaten. Food items originate from production systems that often consist of several production chains made up of chain links. A production chain processes commodities from agriculture, the first chain link, into ingredients for food, and finally food items available for consumption (Gerbens-Leenes et al., 2003).

Fig. 6.1. Simplified overview of the food system that includes a production and a consumption system. A production system consists of agricultural production made up of primary and secondary production that provide a supply of crop and animal commodities, the food industry that applies the supply from primary and secondary production to manufacture food items for consumption, and retailing. A consumption system consists of household consumption defined here as types and amounts of food bought or produced by a household and per capita consumption that concerns the food that is actually eaten. Physical streams flow from agriculture to the food industry, retailing, households and finally to per capita consumption. Sometimes, streams flow in the opposite direction. These opposite streams concern waste streams that are reused in an earlier stage of production. In every chain link of the system, losses take place.

6.2.1 Agricultural production

Globally, agricultural production provides only a limited amount of commodities important for the food system. The fifteen main categories of crop commodities are sugar cane, root crops, vegetables, maize, paddy rice, wheat, fruits, potato, sugar beet, cassave, soybean, barley, pulses, oil seed rape, and sorghum; the six main animal commodities are raw milk, pork, poultry, beef, mutton, and goat meat (FAO, 2004a). For almost all countries starting in 1961, the FAO food balance sheets (FAO, 2004a) provide information on annual, market supply of these commodities.

Four components, water, and the macronutrients carbohydrates, proteins, and fats dominate the composition of commodities (FAO, 2004a; Whitney and Rolfes, 1999; Voedingscentrum, 1998a). The macronutrient content of commodities, such as wheat, soybean, or pork, is genetically determined so that all crop and animal commodities show a specific composition (kg macronutrient per kg dry matter) (Penning de Vries et al., 1989; Schmidt-Nielsen, 1988). Based on composition, the main commodities form four categories: (i) staples, crops that mainly provide carbohydrates and some proteins; (ii) protein rich crops, crops that provide proteins as well as carbohydrates; (iii) oil crops, crops that provide vegetal fats for the production of oil, and carbohydrates and proteins for feed (Penning de Vries et al., 1989); and (iv) animal commodities, commodities that provide high quality proteins and fats (Whitney and Rolfes, 1999). The composition of a commodity determines its suitability for food
items and the function for human nutrition (Whitney and Rolfes, 1999). For example, people consume staple crops, such as wheat and potatoes, for their carbohydrates, pulses for proteins and carbohydrates, while oil crops, such as oil seed rape, provide vegetal oil.

6.2.2 Food industry

The food industry selects and processes commodities from agriculture to manufacture food items (Catsberg and Kempen-van Dommelen, 1997). The food industry often separates commodities into several fractions mainly based on different composition characteristics, such as the content of fat, protein, and carbohydrate. Soybeans, for example, are split into an oil and an oil cake fraction (Kramer and Moll, 1995). Oil is a basic ingredient for margarines, oil cakes for livestock feed. The fractions form the basic ingredients for further production when industry joins and processes ingredients into food items. In the western world, technological developments in agriculture, transportation, and food conservation at the end of the 19th century stimulated the expansion of the food industry and food preparation shifted from households to industry (Jobse-van Putten, 1995).

6.2.3 Household consumption

Household consumption concerns the foods available for a household, either bought in retailing, sometimes produced in homegardens (Fernandes and Nair, 1986; Pallot and Nefedova, 2003). In a household, food preparation into dishes and meals takes place. The repeated arrangements of consumption characterized by types and quantities of food items and their combination into dishes and meals are termed food consumption patterns (Gerbens-Leenes and Nonhebel, 2002). They depend on factors like preference, habit, seasonal availability of foods, household income, convenience, social relations, ethnic heritage, religion, tradition, culture, time constraints, and nutritional constraints.

6.2.4 Per capita consumption

Per capita consumption or human nutrition concerns the food that is actually eaten, either from household food preparation or directly from retailing. Food surveys provide detailed information on nutrition (see also Appendix 2). For nutrition, the composition of food in terms of macronutrients is important because they provide energy and are essential for body functions. Humans can derive energy from different combinations of macronutrients, however. This flexibility contributes to variation among macronutrient composition of consumption and to variation among food consumption patterns.

6.2.5 Physical streams in the food system

Figure 6.1 shows that in the food system, physical streams flow from agriculture to the food industry, retailing, households and finally to per capita consumption. Sometimes, streams flow in the opposite direction. These opposite streams concern waste streams that are reused in an earlier stage of production, for example manure from secondary systems in agriculture, or waste from the food industry for livestock feed (Nonhebel, 2004). In every chain link of the system, losses take place. For example, the food industry processes 1.4 kilograms of wheat to manufacture 1 kilogram of flour (Kramer and Moll, 1995). A study on household consumption in Sweden has estimated that during meals, 10 percent of the food remains behind on the plate and is wasted (Karlsson, 2001). These losses cause a gap between supply from agriculture and actual, per capita consumption.

6.3 Section l, spatial differences among food supply and consumption

6.3.1 Introduction Section l

Per capita food consumption depends, among other things, on income. When income increases, people spend more money on food (Pindyck and Rubinfeld, 2005; Vringer and Blok, 1995). To analyze the relationship among food supply, per capita food consumption, the contribution of animal foods to consumption, and income, this Section assessed spatial differences in 2001 for fifty two countries in different stages of economic development.
6.3.2 Materials and methods Section I

6.3.2.1 Units of calculation

Several studies have shown that natural resource use among food items and consumption arranged in food consumption patterns shows large differences (e.g., Van Engelenburg et al., 1994; Kok et al., 1993; Kramer and Moll, 1995; Gerbens-Leenes et al., 2002). Especially meat, fats, and beverages have relatively large requirements for energy and land (MJ kg⁻¹, m² kg⁻¹). This means that the composition of food consumption has a large impact on natural resource use. For the comparison of trends of per capita food consumption related to average, per capita income, this chapter simplified consumption in terms of macronutrient composition (fats, carbohydrates, and proteins). For most countries, FAO food balance sheets provide information on per capita supply of nutritional energy (kilocalories per day from vegetal and animal products), and supply of proteins and fats (grams per day). The chapter expressed per capita food consumption in the fraction of nutritional energy provided by the macronutrients fats, carbohydrates, and proteins, the macronutrient energy percentage (E%). It expressed the contribution of food items derived from animal systems in the fraction of nutritional energy derived from animal sources (A%), and supply from agriculture in nutritional energy (kilocalories per capita per day). The E% and A% were calculated by

\[
\text{protein E}\% = \frac{P \times \text{kcal.p}}{E} \times 100\% \\
\text{fat E}\% = \frac{F \times \text{kcal.f}}{E} \times 100\% \\
\text{carbohydrate E}\% = \frac{E - ((P \times \text{kcal.p}) + (F \times \text{kcal.f}))}{E} \times 100\% \\
\text{A}\% = \frac{A}{E} \times 100\% 
\]

where \(P\) is the average, daily supply of protein (grams); \(\text{kcal.p}\) the nutritional energy supply of protein (4 kilocalories per gram); \(E\) the average, daily per capita supply of nutritional energy (kilocalories); \(F\) the average, daily supply of fat (grams); \(\text{kcal.f}\) the nutritional energy supply of fat (9 kilocalories per gram); and \(A\) the average, daily per capita supply of nutritional energy from animal sources (kilocalories). The chapter derived data on per capita supply from FAO food balance sheets (FAO, 2004a) and values on nutritional energy for protein and fat from the Dutch Nutrition Council (Voedingscentrum, 1998a).

The chapter assessed spatial variation among food supply, the contribution of animal foods, and the composition of consumption for fifty-two countries in 2001. Appendix 1 shows an overview of these countries. The chapter selected countries from Africa, Asia, Eastern Europe, Latin America, the Middle East, and the OECD, in different stages of development, with more than five million inhabitants. These countries formed two clusters of developed and developing countries, however. It therefore added three smaller transition countries, clustered into a small country group.

6.3.2.2 Income, food supply and per capita consumption

Per capita income depends, among other things, on the development status of an economy, the size of households, and on income distribution in a country. The World Bank (2005a) expresses economies in Gross Domestic Product (GDP). Information on average, GDP per capita is available for most countries from various sources. Maddison (2003), for example, has made a database of the historical, economic development of the world. From the Middle Ages onwards, that database provides information on the economic development status of almost all countries in the world on a national and per capita basis. The database expresses GDP in 1990 International Geary-Khamis dollars (G-K dollars). The Geary-Khamis method is an aggregation method in which international prices and a countries Purchasing Power Parity, depicting relative country price levels, are estimated simultaneously from a system of linear equations and expressed in G-K dollars (United Nations Statistics Division, 2006). This chapter applied average GDP per capita (1990 G-K dollars) as an
indicator for income and combined this with results on food supply and consumption. It derived data from Maddison (2003) since it covers both historic as well as global information.

6.3.3 Results and discussion Section I

The spatial analysis generated three types of results. It showed the relationship between average, per capita income (GDP) on the one hand, and average, daily, per capita food supply, the composition of food consumption, and the contribution of animal foods to consumption, on the other.

6.3.3.1 Per capita income and food supply

Per capita food supply depended on a country’s annual, per capita income (GDP). Figure 6.2 shows that supply varied between 1600 kilocalories per capita per day for low GDPs and 3800 kilocalories for high GDPs, a difference of a factor of almost two and a half. The figure shows that especially for low GDPs, differences per unit of GDP were large, while for high GDPs differences were negligible and saturation occurred. For developed countries, Japan was an exception since it combined a high GDP per capita with relatively small supply.

![Fig. 6.2 Relationship between annual GDP per capita (1990 International Geary-Khamis dollars) and nutritional energy supply (Kilocalories per capita per day). The relationship was based on data from 57 countries in different stages of development in 2001. For an overview of countries, see Appendix B.](image)

6.3.3.2 Per capita income, composition of consumption and contribution of animal foods

Figure 6.3a shows the relationship between the macronutrient composition of consumption and annual GDP per capita. It shows that the fraction of nutritional energy (E%) provided by proteins (the protein E%) was stable, 9-13 E%. The carbohydrate and fat E%, however, showed a relationship with GDP. In countries with low GDPs, people derived nutritional energy mainly from carbohydrates, and a small fraction from fats. In Bangladesh, for example, the country with the lowest GDP in the analysis, people derived 80 percent of nutritional energy from carbohydrates, and 11 percent from fats. For consumption in countries with high GDPs, carbohydrates were less important and more energy was provided by fats. The average consumer in the U.S., France, and Denmark, for example, derived 45 to 50 E% from carbohydrates, and 40 E% from fats. The figure shows that for countries with low GDPs, differences in composition were large; for countries with high GDPs, differences were negligible and saturation occurred at the GDP level of Greece. The average consumer in that country derived 51 percent of its energy from carbohydrates and 36 percent from fats.
Fig. 6.3.a. Fig. 6.3a shows the relationship between annual GDP per capita and the composition of food consumption patterns in terms of the fraction of nutritional energy derived from fat (fat E%), from protein (protein E%), and from carbohydrate (carbohydrate E%). The relationships were based on data from 57 countries in different stages of development in 2001.

Fig. 6.3b. shows the relationship between annual GDP per capita and the composition of food consumption patterns in terms of the fraction of nutritional energy from animal sources (A%). For consumption in countries with low GDPs, A% is almost negligible; for consumption in countries with high GDPs, the fraction is about 25-40 percent.
Consumption in Bangladesh, for example, showed an A% of only 3 percent, while consumption in Denmark had an A% of 40 percent. The figure shows that for low GDPs, differences were large; for high GDPs, differences per unit GDP were smaller. It is stressed, however, that A% indicates the fraction of energy derived from meat, dairy, and eggs of food consumption and not amounts of foods consumed. Some countries with high GDPs, for example Canada and the U.S., showed consumption with relatively small fractions of energy derived from animal sources, 27 and 30 E%. For the average Canadian, the supply of meat was 101 kilograms per capita per year and of raw milk 204 kg. For the average U.S. citizen, the supply of meat was 121 kilograms and of raw milk 262 kg. In an OECD country with a lower GDP than the U.S. and Canada, the Netherlands, on the other hand, people derived 34 percent of nutritional energy from animal sources, but the supply of meat was much smaller than in the U.S. or Canada, only 90 kilograms per capita per year, while the consumption of raw milk was larger, 336 kilograms (FAO, 2004a). The example shows that the fraction of energy derived from animal sources, does not increase infinitely. Jobse-Van Putten (1995) has also shown that in the western world, high income groups consume less meat that low income groups.

In general, animal protein has a better quality than vegetal protein (Whitney and Rolfs, 1999). For all countries, the protein E% of per capita consumption was about the same. An increase of the fraction of nutritional energy derived from animal foods, therefore, does not imply an increase of the fraction of protein but rather an improvement of protein quality. Especially for developing countries, this improves the quality of consumption.

Figure 6.3a and b show that in some countries, consumers deviated from trends. In Japan, for example, a high GDP per capita paralleled a relatively small per capita food supply, while the composition of consumption resembled a pattern related to a lower GDP. This indicates that also other factors than GDP, for example, cultural factors, affect consumption.

6.3.3.3 Uncertainty and inaccuracy of results

Three factors caused uncertainty and inaccuracy of results. These were: (i) data quality; (ii) the use of average data; and (iii) the use of supply data.

Data quality

The chapter derived data on food supply from FAO food balance sheets (FAO, 2004a), and on GDP from Maddison (2003). The FAO obtains data from national datasets. This means that data for different countries probably have different qualities, dependant on the degree of development of national, statistical organizations. Within countries, data quality can differ among years. Major events, like political instability, or improvements of methods of statistical organizations affect data quality. Even for countries with high quality statistical organizations, different sources provide different data. For the Netherlands in 2000, per capita butter consumption, for example, differed by a factor of three among datasets. According to the FAO, the Dutch consume 2.1 kg of butter per capita per year (FAO, 2004a); according to the Statistics Netherlands (CBS) 3.3 kg (LEI-DLO/CBS, 2002); and Eurostat estimates 6.8 kg (LEI-DLO/CBS, 2002). Maddison (2003) also derived data from national statistics. That dataset probably has the same drawbacks as the FAO dataset.

The use of average data

The second factor that contributed to uncertainty and inaccuracy was the use of average data. Per capita data derive from information on a national level, and are therefore average numbers. In some countries, income distributions are large and differences in food consumption occur among population groups. These differences are not reflected in national data. This means that the use of average data underestimates trends found in here.

The use of supply data

The third factor for uncertainty and inaccuracy for the comparison was the use of FAO supply rather than consumption data. Before food is available for per capita consumption, commodities and foods pass complete food chains, from farm to fork, in which a number of processes takes place to produce the final foods. In all chain links and transportation between links, losses take place. The size of the gap between supply and per capita consumption is not precisely known, but it can be argued that long chains have larger losses than short chains. Sometimes, people produce food outside the market, for example in home gardens (Fernandes and Nair, 1986; Pallot and Nefedova, 2003). The FAO food balance sheets provide supply data on a national level and do not take nonmarket production into account (FAO, 2004a). For low GDPs, the chapter found a ratio of supply over physical requirements of about 1.0. For high GDPs, however, the ratio was larger, about 1.8, indicating that about half of
supply is not eaten at all. By excluding nonmarket production, the chapter underestimated supply. Neglecting losses in food chains could have had effects on the assessments.

6.3.4 Conclusions Section I

Differences in annual GDP per capita among countries paralleled differences in the composition of per capita food consumption. In all countries investigated, the fraction of nutritional energy derived from protein was 9-13 E%. For consumption in countries with low GDPs, the fraction from fat was about 11 E%, from carbohydrate 80 E%, and the fraction from animal sources 3 percent. For consumption in countries with high GDPs, the fraction from fat was 35-40 E%, from carbohydrate 45-50 E%, and the fraction from animal sources 30-40 percent. Total supply ranged between 1600 kilocalories per capita per day for countries with low GDPs, and 3800 kilocalories for countries with high GDPs. The largest differences per unit of GDP occurred for relatively low GDPs, i.e. below 5000 1990 International Geary-Khamis dollars (G-K dollars) per capita per year. GDP levels between 5000 and 12 500 G-K dollars showed smaller differences. Above a GDP level of 12 500 G-K dollars, supply did not increase and the composition of consumption and contribution of animal foods to consumption did not show large differences among countries.

6.4 Section II, the use of supply data

6.4.1 Introduction Section II

For the comparison of the composition of per capita consumption and the contribution of animal foods, Section I derived supply data from the FAO food balance sheets. To analyze the use of supply rather than per capita consumption data, Section II compared differences in composition between supply and per capita consumption. Next, it evaluated the size of the gap between supply and actual, per capita consumption in relation to per capita income (GDP).

6.4.2 Materials and methods Section II

Information on market supply of commodities is available for most countries. Information on per capita consumption, i.e. the amount and types of food that people actually eat, is scarcer, however. Food surveys provide information on nutritional characteristics of per capita consumption for a representative population group in a specific country (FAO, 2005). They provide data on nutritional energy intake (kilocalories per capita per day), and most surveys provide data on the fraction of nutritional energy from the macronutrients fats, carbohydrates, and proteins, the macronutrient energy percentage (E%). Some surveys make a distinction between rural and urban population groups. A number of surveys has been performed in developing countries (FAO, 2005), two time series are available for developed countries, the Netherlands (Voedingscentrum/TNO, 1998b) and the United States (USDA, 2005). Appendix B shows an overview of these surveys. To analyze differences between FAO supply data used in Section I and actual, per capita consumption data, this section compared the composition of per capita consumption and related supply. Every commodity has a specific composition in terms of macronutrients, such as fat E%. Results of Section I showed that the contribution of protein to nutritional energy of consumption, the protein E%, was stable but that differences occurred between fat and carbohydrate E%, reflecting a difference in the composition of consumption. This Section assumed that a difference in fat E% between supply and per capita consumption reflects a difference of composition. For the comparison, the section used information on the fat E%. It obtained data on fat E% from eighteen food surveys. Appendix 2 marked these surveys with an asterix *. The section calculated the fat E% of related supply using equation 2 from Section I and derived data from the FAO (2004a).

Section I showed that food supply increases along with increasing GDP. To evaluate the size of the gap between supply and actual, per capita consumption, Section II assessed the relationship between nutritional energy intake (kilocalories per capita per day) and average, annual GDP per capita. It combined data from thirty one food surveys from twenty six countries (see Appendix B) with information on GDP from Maddison (2003).
6.4.3 Results and discussion Section II

6.4.3.1 The composition of supply and consumption

Figure 6.4 shows that the fat E% of supply and actual, per capita consumption were in the same order of magnitude, indicating that macronutrient compositions were the same. Eventual losses or nonmarket production did not cause shifts in composition. This justified the use of supply rather than consumption data for the analysis of per capita consumption in Section I.

Fig.6.4. Comparison between the fraction of nutritional energy derived from fat (fat E%) of actual consumption and of related supply. Data on fat E% of consumption derived from food surveys, the fat E% of related supply was calculated from FAO food balance sheets.

6.4.3.2 Per capita income and nutritional energy intake

Available food surveys were performed in countries with large differences in per capita income (GDP). Sixteen food surveys indicated nutritional energy intakes between 2000 and 2500 kilocalories per capita per day, which is in the range of actual requirements (Whitney and Rolfes, 1999). Eight surveys indicated intakes between 1700 and 2000 kilocalories, while five studies report intakes over 2500 kilocalories per capita per day. This thesis found no relationship between nutritional energy intake and annual GDP per capita, however. For the Netherlands and the U.S., two countries with high GDPs, energy intakes were between 2000 and 2500 kilocalories per capita per day. This is in the same order of magnitude than intakes in countries with low GDPs. Twelve food surveys have made a distinction between rural and urban consumption but did not find substantial differences among energy intakes. It can be argued that the physical requirement of the human body determines the quantity of nutritional energy intake. Section I showed that the increase of GDP per capita went along with larger supply. The comparison of food surveys showed that per capita consumption did not increase. The increase of the gap between supply and per capita consumption, therefore, is likely to result from larger supply.

6.4.3.3 Uncertainty and inaccuracy of results

Section I discussed uncertainty and inaccuracy caused by the use of the FAO and Maddison datasets. Another reason for uncertainty and inaccuracy is that the chapter derived information from food surveys that were probably all performed in a different way, generating different types of inaccuracies and uncertainties. For example, people tend to underreport consumption (CBS, 1994; Kok et al., 1993). The way food surveys have addressed this effect has probably differed among
surveys, generating different inaccuracies. The lowest value was for the Philippines, 1800 kilocalories per capita per day, which is below physical requirements, the highest for Jordan, 3200 kilocalories per capita per day, far above physical requirements. The examples show that methods among surveys have probably differed generating under and overestimations.

6.4.4 Conclusions Section II

It can be concluded that for the assessment of changes in the composition of per capita food consumption and the contribution of animal foods to consumption, the use of FAO supply data did not lead to other results than the use of actual consumption data. GDP increase did not have an effect on nutritional energy intake, which is stable and reflects physical requirements. The increase of food supply (kilocalories per capita per day), therefore, is not caused by an increase of consumption but reflects an increasing gap between supply and per capita consumption along with increasing income.

6.5 Section III, temporal differences among food supply and consumption

6.5.1 Introduction Section III

Over the last millennium, Europe has shown continuous economic growth (Maddison, 2003). Between 1700 and 2000, for example, in France, average GDP per capita increased from 900 to 21 000 1990 International Geary-Khamis dollars (G-K dollars), in Great Britain, from 1250 to 20 000 G-K dollars. Between 1961 and 2001, Italy, Greece, Spain, and Portugal showed a three to four fold increase of average GDP per capita. These periods went along with large changes of food consumption (Jobse-Van Putten, 1995; Fogel and Helmchen, 2002; FAO, 2004a). Section I analyzed the effect of income (GDP) on food supply and per capita consumption for countries in different stages of development in 2001. To evaluate if trends also exists within countries, Section III made two time trends, for per capita supply in France and Great Britain, and for supply and consumption in southern Europe.

6.5.2 Materials and methods Section III

Studies of historic food consumption often describe changes in a qualitative way (e.g. Mennell et al., 1992; Jobse-Van Putten, 1995) and do not provide quantitative data. An exception is the analysis of Fogel and Helmchen (2002) that has quantified nutritional energy supply for France and Great Britain between 1700 and 2000 (kilocalories per capita per day). To evaluate per capita food supply over time, the section first made a three century time trend for supply in France and Great Britain. It combined data (kilocalories per capita per day) from Fogel and Helmchen (2002) with GDP data (G-K dollars) from Maddison (2003). Second, the section made a four decade time trend (1961-2001) for food consumption in southern Europe. For Italy, Spain, Portugal, and Greece, it assessed the increase of per capita supply, changes in the composition of food consumption, and changes in the contribution of animal foods. For the comparison of composition, it applied equations 1-3 from Section I, for the comparison of the contribution of animal foods, it applied equation 4. The section derived data from the FAO (2004a). Next, it combined data on supply (kilocalories per capita per day), results on composition (macronutrient E%), and contribution of animal foods (A%) with data on income (GDP in G-K dollars) from Maddison (2003).

6.5.3 Results and discussion Section III

6.5.3.1 Food supply in France and Great Britain, 1700-2000

Figure 6.5 shows that in France and Great Britain, increasing GDP per capita paralleled larger food supply. Per capita supply doubled over the three centuries considered, from 1700 kilocalories per capita per day in 1700 to 3500 kilocalories in 2000. The largest increase per unit of GDP occurred for values below 5000 G-K dollars, above this level, the increase gradually slowed down. The figure also shows the function based on the spatial analysis of Section I. Results for food supply in France and Great Britain were in the same order of magnitude than results of the spatial analysis.
6.5.3.2 Food supply and consumption in southern Europe, 1961-2001

Figures 6.6a-c show results for southern Europe in the period 1961-2001. Figure 6.6a shows that per capita, daily, nutritional energy supply increased from 2500 kilocalories per capita per day for a GDP of 3000 G-K dollars (Portugal, 1961) to 3700 for a GDP of 12 500 G-K dollars (Greece, 2001). Figure 6b shows changes of the composition of food consumption. For protein, the E% varied between 13 and 18 E%, but was independent of GDP. For carbohydrate and fat, changes occurred. Increasing GDP paralleled a decrease of the fraction of nutritional energy derived from carbohydrates, and an increase from fats. For GDPs below 5000 G-K dollars, the carbohydrate E% was 60-70 E%, the fat E% 20-30 E%. The composition stabilized at an annual GDP of 12 500 G-K dollars. At this level, people derived 45 E% from carbohydrates and 40 E% from fats. Figure 6c shows the increase of the fraction of energy from animal sources (A%). A% was relatively small for low GDPs, the smallest value was 13 A% for a GDP of 3400 G-K dollars (Greek consumption, 1961). For a GDP of 14 200 G-K dollars (Portuguese consumption, 2001), the A% was 30 percent. Although GDPs of southern Europe fell outside the trajectory below 3500 and above 19 000 G-K dollars, when figure 6a-c was compared to Figure 6.2a-c, results were in the same order of magnitude than results of the spatial analysis.

6.5.3.3 Comparison of results with information from food surveys

To evaluate if information from food surveys could confirm trends found in here, the chapter compared the fat E% of per capita consumption derived from eleven surveys in developing countries that made a distinction between urban and rural patterns. Figure 6.7 shows the results. Except for Egyptian consumption, urban per capita consumption had a larger fat E% than rural consumption. The surveys were done in countries with relatively low GDP per capita, i.e. within the trajectory where large differences in composition of food consumption occur per unit of GDP. It is likely that GDPs were higher for urban populations, a factor that explained the difference of fat E%. This confirmed results of this chapter.

6.5.3.4 Uncertainty and inaccuracy of results

All factors that contributed to uncertainty and inaccuracy of results in Section I and II also contributed to uncertainty and inaccuracy of Section III. Moreover, the historical analysis of Fogel and Helmchen (2002) has reported average, daily, nutritional energy intakes below physiological requirements. In
In general, nutritional energy requirements are constant per unit of body mass (Whitney and Rolfes, 1999). Average energy intakes below the physiological requirement, might be possible, however, when the fact that three centuries ago, people were smaller and had more children, with less body mass, is taken into account.

**6.6a**

![Graph showing the relationship between annual per capita GDP and nutritional energy supply](image)

**6.6b**

![Graph showing the development of macronutrient supply in Southern Europe from 1961 to 2001](image)
6.6c

Fig. 6.6a-c. Fig. 6a shows the relationship between annual GDP per capita (1990 International Geary-Khamis dollars and nutritional energy supply (kilocalories per capita per day) for southern Europe between 1961 and 2001. The figure also shows the function based on the spatial analysis of Section l. Fig. 6.6b. shows the relationship between annual GDP per capita and the composition of food consumption patterns in terms of the fraction of nutritional energy derived from fat (Fat E%), from protein (Protein E%), and from carbohydrate (Carbohydrate E%) for southern Europe between 1961 and 2001. Fig. 6.6c shows the relationship between annual GDP per capita and the composition of food consumption patterns in terms of the fraction of nutritional energy from animal sources (%) for southern Europe between 1961 and 2001. The figure also shows the function based on the spatial analysis of Section l. The relationships were based on data from Italy, Greece, Spain, and Portugal.

Fig. 6.7. Fraction of nutritional energy derived from fat (fat E%) for urban and rural populations in nine countries in different years. The comparison was based on data from eleven food surveys in developing countries (for an overview, see Appendix B).
6.5.4 Conclusions Section III

France, Great Britain, and southern Europe showed the same trends as obtained in the spatial analysis. Higher GDPs favored larger supply, larger fractions of nutritional energy from fats, and larger contribution of animal foods; at the same time, the fraction derived from carbohydrates decreased. The fraction of energy from protein was stable. The largest changes occurred for relatively low GDPs, above an annual GDP per capita of 12 500 G-K dollars, food supply and per capita consumption were stable.

6.6 General discussion

6.6.1 Trends

The general impression that in western countries per capita food consumption expressed as nutritional energy intake has increased over the last decades is not in accordance with results presented here. Nutritional energy intake is far more constant than food supply or the composition of consumption, and reflects physical requirements. Along with increasing income, the size of the gap between actual, per capita consumption and supply (kilocalories per capita per day) increases, not physical consumption. An explanation is that affluent countries with high GDPs also have better developed food industries with longer food chains, and probably larger losses, than countries with low GDPs. Another explanation is that in countries with low GDPs, where food is more scarce, people prepare and consume food more efficiently and in this way generate less and smaller waste streams. The FAO food balance sheets do not provide information to confirm this hypothesis, however. The evaluation of the increasing gap between supply and per capita consumption that parallels increasing GDP requires further research.

Results of the spatial and temporal analyses all show the same patterns of change. The largest changes in food supply and per capita consumption occurred for relatively low GDPs, below 5000 G-K dollars, between 5000 and 12 500 dollars changes were relatively small, above an annual GDP per capita of 12 500 G-K dollars, food supply and the composition of consumption were stable. This is in accordance with many studies that have shown that increasing societal affluence causes shifts in the consumption of specific foods and commodities. By simplifying per capita consumption further than assessments of existing studies, and by adding the aspect of economic development stage, the thesis identified strong similar trends. However, it should be realized that this chapter addressed composition rather than absolute amounts of food. As a result, some countries with high GDP showed a relatively low contribution of animal foods while absolute consumption was large.

Although uncertainties occurred, all analyses showed similar directions of change. Despite the use of rough estimates, differences among countries, developments in time, as well as differences between urban and rural populations, all showed the same trends. It is stressed, however, that results obtained here cannot be interpreted at face value. They give an indication of the direction of changes of food supply, the composition of consumption, the contribution of animal foods, and their magnitudes. In combination with estimates of GDP increases, the method presented here provides a tool to quantify these changes, and indicate where and when they will probably take place.

6.6.2 Future changes

The most important finding of this paper is that the main changes occur for per capita, annual incomes below 12 500 G-K dollars. If trends found in here are also valid for the future, this has important consequences for food security in the coming decade. Today, about 85 percent of the total world population lives in six regions: (i) the OECD countries; (ii) Latin America; (iii) Africa; (iv) China; (v) India; and (vi) the rest of Asia. Table 1 shows the nutrition, GDP and population characteristics of these regions.

In four regions, per capita income levels (GDP) are below 5000 dollars per year, i.e. within the trajectory where the largest changes in food supply, composition of consumption, and contribution of animal foods occurred. China, India, and the rest of Asia combine low GDP per capita with large growth rates. This means that in the next ten years, large changes are likely to occur in Asia. If the Asian countries maintain economic growth along existing lines, the period 2006-2015 might show a substantial increase of per capita food supply, while the composition of consumption might shift towards the affluent patterns of western countries, characterized by large consumption of fats and animal foods, and small consumption of staples. For Latin America and Africa, economic growth will
probably be small. Here, population growth will be the main driver for increasing total food demand. For the OECD, no substantial changes are likely because food consumption in these countries have already reached their saturation levels and population size is more or less stable.

Table 6.1
Per capita nutrition characteristics in 2001, GDP characteristics (Geary-Khamis dollars), expected national GDP growth, and population characteristics for six regions that include 85% of the global population

<table>
<thead>
<tr>
<th>Region</th>
<th>Energy supply(b) (kcal)</th>
<th>Fat E%</th>
<th>Protein E%</th>
<th>Energy from animal sources (%)</th>
<th>Annual, per capita GDP 2001</th>
<th>National GDP growth</th>
<th>Annual, GDP per capita 2015</th>
<th>Size 2001 (billion)(e)</th>
<th>Annual growth(f)</th>
<th>Size 2015 (billion)(**)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>2953</td>
<td>26</td>
<td>11</td>
<td>20</td>
<td>3800</td>
<td>6,9%</td>
<td>9671</td>
<td>1.29</td>
<td>0.7%</td>
<td>1.42</td>
</tr>
<tr>
<td>India</td>
<td>2385</td>
<td>19</td>
<td>9</td>
<td>8</td>
<td>1926</td>
<td>4,0%</td>
<td>3335</td>
<td>1.03</td>
<td>1.4%</td>
<td>1.25</td>
</tr>
<tr>
<td>OECD</td>
<td>3493</td>
<td>36</td>
<td>12</td>
<td>27</td>
<td>21538</td>
<td>1,8%</td>
<td>27648</td>
<td>0.89</td>
<td>0.4%</td>
<td>0.94</td>
</tr>
<tr>
<td>Asia(a)</td>
<td>2540</td>
<td>18</td>
<td>9</td>
<td>9</td>
<td>2760</td>
<td>2,1%</td>
<td>3692</td>
<td>0.76</td>
<td>1.3%</td>
<td>1.20</td>
</tr>
<tr>
<td>Africa</td>
<td>2519</td>
<td>18</td>
<td>10</td>
<td>7</td>
<td>1615</td>
<td>0,6%</td>
<td>1756</td>
<td>0.52</td>
<td>2.6%</td>
<td>0.74</td>
</tr>
<tr>
<td>Latin America</td>
<td>2905</td>
<td>26</td>
<td>11</td>
<td>20</td>
<td>6174</td>
<td>1,2%</td>
<td>7296</td>
<td>0.45</td>
<td>1.3%</td>
<td>0.54</td>
</tr>
</tbody>
</table>

a. Without China and India
b. Source: FAO, 2004a
c. Source: Maddison, 2003
d. Kilocalories per capita per day
e. Source: FAO, 2005
f. Source: FAO, 2003a

For the estimation of food demand for the period 2003-2030, the FAO (2003) has indicated that developing regions will show a shift towards larger food supply (kilocalories per capita per day), as well as larger consumption of specific commodities, such as cereals, sugar, oils, and animal foods, while consumption of pulses, roots, and tubers will decrease. When information from this chapter is combined with estimates of GDP growth, results can contribute to the scenario analysis of the FAO. This chapter showed that for the Asian regions, changes might occur faster than expected by the FAO projections (FAO, 2003a) and that in the coming ten years a continuation of present trends might cause a large pressure on agriculture. The European transition occurred gradually, enabling agriculture and trade to keep pace with the growth of demand. A continuation of present economic trends might cause a large pressure on the food system within ten years because changes occur much faster than present projections indicate and cause additional pressure on the global food system as well as on scarce natural resources, such as land, energy and water. These trends coincide with environmental pressure on the food system, global warming and climate change. In combination, these pressures form an enormous challenge for the system to supply sufficient food for the growing world population.