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INCOME ELASTICITY FOR ANIMAL-BASED PROTEIN AND FOOD SUPPLY

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Income Elasticity for Animal-Based Protein and Food Supply

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Abstract:

Dietary choices are one of the main causes of mortality and environmental degradation. Plant-based diets, in comparison to diets rich in animal products, are considered to be more sustainable because they use fewer natural resources and come with a lower environmental burden, resulting in lower greenhouse gas emissions in particular. However, the rapid increase in global population and wealth has led to an increased demand for foods of animal origin. Getting enough protein might be one of the reasons people consume animal products but its increased consumption could negatively impact our health and environment. Hence, the aim of this paper is to examine the economic and sociodemographic factors that influence the amount and the share of animal food intake as well as the amount and the share of animal-based protein in the worldwide diet. An econometric analysis of country-level panel data allows us to investigate the Environmental Kuznets Curve hypothesis in the context of a sustainable diet. The findings suggest that the relationship between GDP per capita and animal-based food and protein supply resembles an inverted U-shaped curve. In the global analysis, the turning point is estimated to be around $81,500 in relation to both the share of animal food supply and the share of animal proteins. The resulting income elasticity shows to be inelastic across the domain, however, the specific values vary depending on the country's level of GDP. The elasticity is positive for low- to middle-income countries with its maximum of 0.29; and it becomes negative once a country reaches a GDP level of about $77,000-$81,000.

JEL: Q11, Q56, C33, C52, O13

Keywords: GDP, Environmental Kuznets curve, animal consumption, animal protein, healthy and sustainable diet, panel data analysis

1 Introduction

Current dietary patterns combined with the way how the food is produced were shown to be unsustainable (Loken et al. 2020). Research by Gerten et al. (2020) shows that globally, there is enough food to feed everyone, however, planetary boundaries are not being taken into account. It was estimated that if we did respect planetary boundaries, but without changing the way we produce, consume and waste food, we would manage to feed only 3.4 billion people. The results imply that if we want to respect planetary boundaries and provide food for everyone on this planet, the emphasis should be on shifting our dietary patterns as well as changing food production practices and reducing food loss and waste. The focus of this paper is specifically on dietary patterns and the consumption of animal products. In addition to that, factors that influence the consumption of animal proteins will be analysed since there have been projections that the global demand of animal-derived protein will double by 2050 (Henchion et al. 2017). Therefore, it is essential not only to look at what affects the consumption of animal products but also to analyse determinants of the increased demand for animal proteins.

In order to mitigate the negative effects of increased consumption of animal-based products while taking into account the nutritional aspects of healthy diets, it is crucial to firstly understand which elements have an impact on how much of animal products or animal-based protein people have in the diet. Specifically, this paper examines factors that might influence the amount and the share of animal products in our diet as well as the amount and the share of animal-based protein out of the total dietary protein, with a special focus on the impact of income. The objective is to verify whether the relationship between GDP per capita and the share of animal products (and animal-derived proteins) resembles the Environmental Kuznets Curve (EKC).

Grossman and Krueger (1992) used the concept of Kuzents Curve and extended it to relate economic growth with environmental indicators. In their case, sulphur emissions were used as a proxy for air pollution, however, other variables representing environmental degradation have been employed, such as sulphur or CO_2 emissions (Selden and Song (1994), Shafik (1994), Panayotou (1997)), water pollution (Shafik 1994), biodiversity loss (Dietz and Adger (2003), Hoffmann (2004)) or deforestation rates (Chiu (2012), Mills and Waite (2009)). In our case, the amount and the share of animal products (and proteins) is considered to approximate the level of environmental, and possibly health, deterioration. Besides a global assessment, the EU analysis is carried out to estimate the economic and socio-demographic factors that influence the value of animal products and proteins in absolute and relative terms.

Because the association between economic variables and the share of animal-based protein in the diet has not been examined much yet, evaluating what determines the amount of protein we get from animal sources might bring new insights into how to promote healthy and sustainable diets. It is especially important when considering the negative externalities that come along with increased consumption (and production) of animal-derived food products. Firstly, the current animal agricultural practices pose a great threat to the environment since they contribute largely to greenhouse gas (GHG) emissions, biodiversity loss, acidification and eutrophication. Secondly, there have been several studies suggesting that the consumption of large quantities of animal products, especially highly processed meat, is associated with various health problems, such as type 2 diabetes, cardiovascular diseases and total mortality (Willett et al. 2020). This paper might help relevant stakeholders identify important factors associated with increased consumption of animal-based foods. Based on that, policy-makers can evaluate which instruments would be suitable to facilitate a shift towards more sustainable diets that aim to lower the amount of animal products that are being consumed. Answering this question might also be valuable for them to better target goals concerning environmental sustainability and food security. On a global scale, we might be able to see how increases in income per capita are associated with changes in the amount and the share of animal products and proteins, and what is to be expected to happen in developing countries if there are no other adjustments.

In order to answer the research question, a comprehensive analysis of past trends and the current state of sustainable diets as well as the inspection of externalities related to increased consumption of animal products were made. After that, econometric analyses of panel data were conducted in R using data from FAO (2021), UN (2021), NCD-RisC (2021), CCKP (2021) and OECD (2021) databases. Several model specifications were tested on two samples (global and the EU). The Fixed Effects method was employed to account for the unobserved time-invariant factors.

The paper is structured as follows: section 2 provides a review of recent literature about healthy and sustainable diets as well as the factors that play a huge role in the consumption of animal-based food products. In section 3, the main terms from the field of nutrition that are referred to throughout the paper are defined and the theoretical background is set. Then, section 4 presents the empirical model, including data specification, which is followed by the panel data model, where the econometric theory behind the models is explained. The results, both descriptive and from the regressions, are shown in section 5 and discussed in section 6. Finally, section 7 summarizes our findings.

2 Literature review

Consumers' habits have been steadily changing due to the globalization and market liberalization (Kovljenic and Savic 2017). In particular, agriculture has been influenced continuously by challenges and changes predominantly caused by economic factors, however, climate change, rise in prices and changes in consumer habits have played an important role, too. Global food systems are therefore shaped by major demographic and economic transitions (Kovljenic and Savic 2017). Income growth is considered as one of the drivers for demand for food. As we move from low-income to high-income countries, the marginal share of income spent on food decreases. As an example, an average household in the EU spends approximately 15% of their income on food (Valin et al. 2014). Consumers in countries such as the US, Singapore, Australia or Austria spent around 8% of their income on food in 2015, whereas the expenditure spent on food in African or Asian countries ranged from 40% to almost 57% (Gray 2016). Furthermore, as income increases, the consumption patterns change to a more diverse diet, which consists of a greater share of animal protein, fats and oils (Kovljenic and Savic 2017).

Kovljenic and Savic (2017) found that number of household members, housing costs and ability of a household to pay necessary expenses significantly affect the demand for food products. Also, the findings by Lee et al. (2013) imply that food prices and affordability are important factors of our food choices, dietary patterns, nutrition and health. Gossard and York (2003) discuss not only the economic or environmental significance of meat production but also the social significance of meat consumption. Their findings suggest that gender, race, ethnicity, location of residence, such as region and urban vs.

non-urban areas, and social class have an effect on dietary habits - the total amount of meat and the amount of beef consumed. The authors conclude that these social-structural factors, together with macroeconomic and psychological factors, are likely to explain our consumption patterns.

From the macroeconomic perspective, Muhammad et al. (2017) analysed income and own-price elasticities for several food groups in different regions. They focused on how income and food prices influence global dietary intakes by age and sex by assessing evidence from 164 countries. They argue that there are heterogeneous associations among prices, income and food intakes, which depend mainly on regional differences but sometimes they vary across demographic groups within the regions (e.g. sex, age). Most of the own-price elasticities resulted to be negative. From the animal-based products, processed meat and fish were among the most price sensitive categories.

Besides scientific articles, several reports thoroughly examine the topic of sustainable and healthy diets. Willett et al. (2020) aim to “develop global scientific targets based on the best evidence available for healthy diets and sustainable food production”. Conditional on these global targets, a safe operating space for food systems might be defined, which allowed them to evaluate which diets and food production practices would be in accordance with the UN Sustainable Development Goals (SDGs) and Paris Agreement. They propose a healthy reference diet, consisting of mainly vegetables, fruits, whole-grains, legumes, nuts, with the inclusion of smaller amount of animal products, refined grains and starchy vegetables. The focus is put on environmental sustainability of food production and health implications of food consumption. At the same time, they argue that multiple stakeholders must be involved to make this transformation of food systems possible.

In addition to that, FAO and WHO (2019) published *Sustainable healthy diets – Guiding principles* to support the efforts of countries that seek to transform their food systems to achieve sustainable healthy diets. While being focused on food and taking into consideration nutrient recommendations, the publication also considers economic, environmental and social sustainability. Similarly, Loken et al. (2020) analyse the topic of sustainable diets in their report *Bending the curve: The restorative power of planet-based diets.* They present a holistic approach focused on three pillars of the food systems – sustainable production, healthy and sustainable diets, and food loss and waste. Their objective is to establish food systems that provide nutritious food to present as well as future generations, whilst taking into account our planet and its boundaries. By assessing how diets affect various environmental and health indicators, they introduce the topic of planet-based diet. They argue for its restorative power and how planet-based diets could enable countries accomplish environmental sustainability and achieve human health objectives.

Until now, scholars have been studying mainly the impact of food products in general or animal-based products in particular, however, the association between economic variables and the amount and the share of animal-based protein in the diet has not been examined much yet. Evaluating what determines the amount of protein we get from animal sources, as well as how much food of animal origin we eat, might bring new insights on how to promote healthy and sustainable diets.

The novelty that our research brings lies in assessing the economic impact on the amount and the share of foods and proteins of animal origin on a global level. There has been plenty of work on a micro-economic level but we would like to analyse the links between the above-mentioned variables from a macro-economic perspective to get an overall picture of the current state on how much protein, and food in general, comes from animal sources and how it is related to GDP.

3 Background

Good-quality diet

Diets around the world differ because of several factors, however, a good-quality diet can be characterised by the following four aspects: variety and diversity within and across food groups, adequacy, moderation and overall balance. A healthy diet "protects against malnutrition in all its forms, as well as non-communicable diseases (NCDs) such as diabetes, heart-disease, stroke and cancer" (WHO 2020). Depending on gender, age, physical activity level and physiological state, it should ensure that the individual's needs for macronutrients and essential micronutrients are met. It ought to include plenty of vegetables, fruit, legumes, nuts and whole-grains. At the same time, less than 10% of the total energy intake should be obtained from free sugars and less than 30% from fats, where unsaturated fats are preferable to saturated fats (WHO 2020).

A large body of scholars draw attention to the importance of sustainable diets in terms of environmental sustainability. Research by Willett et al. (2020) centers around developing global scientific targets subject to the best evidence that is available for healthy diets and sustainable food production. The authors provide a framework for a universal healthy diet that serves as a benchmark to evaluate health and environmental impacts compared to standard diets. According to FAO and WHO (2019), sustainable healthy diets are "dietary patterns that promote all dimensions of individuals' health and well-being; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable". They aim to achieve the optimal growth and development of all individuals together with supporting physical, mental and social well-being throughout the whole life for present and future generations. Therefore, the objective is to prevent all forms of malnutrition, lower the risk of diet-related NCDs and support the preservation of biodiversity and planetary health.

The focus of this paper is on proteins since they are essential to maintain good health. They are important for growth and maintenance of tissues and cells. The requirement for dietary protein changes throughout the life but a general recommendation is to consume approximately 0.8 g of protein per kg of body weight per day. This roughly equals to 56 g of protein a day for a 70 kg individual, which is approximately 10% of energy intake (Willett et al. 2020). Otten et al. (2006) introduce the term Acceptable Macronutrient Distribution Range (AMDR), which defines a range of intake for a particular energy source that is associated with a reduced risk of chronic disease, such as coronary heart disease, obesity or cancer. For adults, the AMDR for protein is $10 - 35\%$ of total energy intake.

Existing protein sources can be divided into two groups - vegetal and animal sources. Both of them differ in their digestibility, bioavailability and quality, however, if the recommended total protein consumption is met and if it is consumed from a variety of sources, the lack of quality or digestibility should not be of a concern (Henchion et al. 2017). Loken et al. (2020) showed that 63% of global protein supply comes from plant-based sources while the remaining 37% is derived from meat, dairy and other animal products.

FAO data clearly show that there has been a significant increase in global meat consumption in the past few decades (Figure A.1). In 2018, the global meat production reached 342 million tonnes. Compared to 2000, the amount increased by 47% (around

109 million tonnes) (FAO 2020). Almost 90% of the world meat production in the past 20 years can be attributable to raising pigs, chicken and cattle. According to WRAP (2019), this trend will continue and the global meat production is predicted to double between 2000 and 2050. Hence, several non-profit organizations (NGOs) and governments are carrying out campaigns to reduce consumption of meat (Henchion et al. 2017) because of high resource needs and the negative impact on local as well as global environments (WRAP 2019). Willett et al. (2020) propose a healthy reference diet, which takes into consideration both health and environmental implications. Based on this reference diet, they compared current dietary intakes globally and in various regions. Globally, the main problems are red meat, starchy vegetables and eggs. The intakes of red meat, eggs, poultry and dairy exceed the reference value in most of the developed regions.

Unhealthy and unsustainable diets

Diet in higher income countries includes a great share of animal-based foods. Estimations from the US adult population suggest that 62% of dietary protein comes from animal products and only 30% is obtained from plant-based sources. Similarly, Finnish women and Finnish men get 65% and 69% of their total protein intake from animal sources, while it is only 29% and 25% for plant-based foods, respectively (Paivarinta et al. 2020). Recent trends illustrate that developing countries have been experiencing the rise in demand for the animal-based protein. Hence, it is expected that the global demand for animal-derived protein will increase. There are some projections suggesting that this demand will double by 2050 (Henchion et al. 2017), therefore, it is essential to look at the side effects of the increased demand for animal products.

A report by Willett et al. (2020) presents the findings from several studies and meta-analyses related to health implications of the consumption of animal products, such as meat, fish, dairy and eggs. In particular, the consumption of red meat, specifically processed red meat, was correlated with increased risk of cardiovascular disease, stroke, type 2 diabetes and a linear association between red meat and total mortality was found. In addition to those findings, the International Agency for Research on Cancer classified processed red meat as a group 1 carcinogen, and unprocessed red meat as a group 2 carcinogen, due to the evidence related to colorectal cancer. There is also an increased risk of breast cancer associated with higher intakes of read meat during adolescence and early adult life.

A large prospective cohort analysis by Song et al. (2016) found a substantially reduced overall mortality when replacing protein from animal sources with protein from plant sources, especially among participants who had at least 1 lifestyle risk factor. They conclude that the source of protein is indeed important as substituting animal protein (especially from processed red meat) with plant protein might result in lower mortality.

Estimating the precise environmental footprint of individual food products poses a great challenge due to methodological inconsistencies and lack of data. The majority of studies focus on evaluating GHG emissions, whereas the impact on other key environmental dimensions, namely biodiversity, animal welfare, nutrient leaching and the use of chemicals, is under-represented and under-analysed. Nevertheless, some scholars have been trying to assess these environmental impacts, which is summarised in Figure 1 (Willett et al. 2020). Five environmental indicators - GHG emission, land use, energy use, acidification potential and eutrophication potential - were evaluated and the environmental impact of individual food groups expressed in serving of food is shown as a mean value (and standard deviation) in the graph. Plant-based foods result in lower negative environmental effects than animal-based foods in all five categories. In addition to the impact of various food groups, the effect of overall dietary patterns has been evaluated. Most of the studies agree that higher the replacement of animal-sourced foods with plant-based foods, lower the environmental burdens. Consequently, greatest reductions in GHG emissions and land-use are associated with vegan and vegetarian diets and largest reductions in water use are associated with vegetarian diets (Willett et al. 2020).

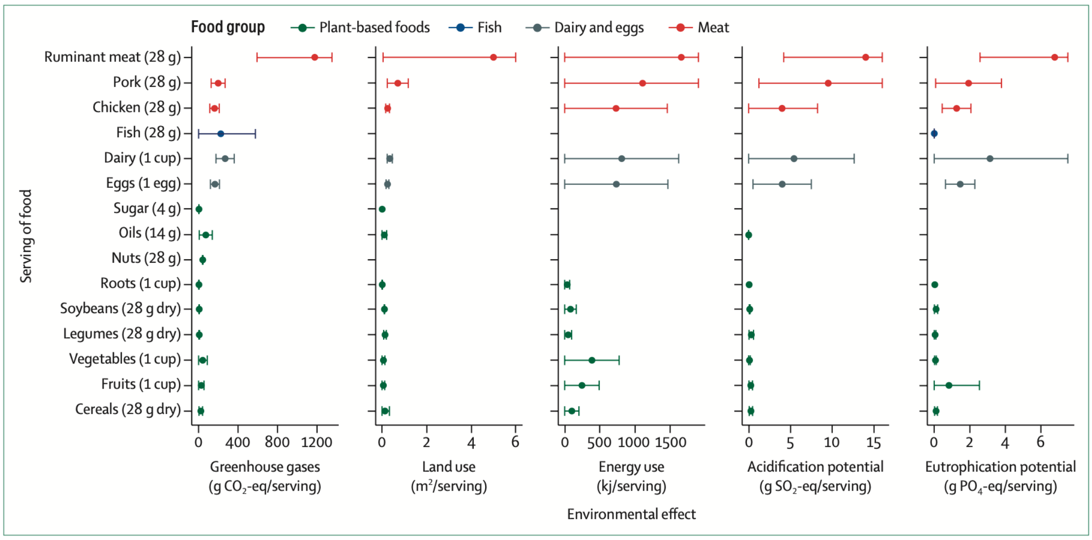

Figure 1: Environmental effects per serving of food produced, Source: Willett et al. (2020).

Factors of diets: Maslow's Theory of Needs

We might suspect that as economy grows, the amount of animal-based products in the diet and subsequently, the amount and the share of animal protein, increases. On the other hand, when people's basic needs are satisfied, they tend to focus on meeting more complex needs, e.g. choosing the products that do not harm our environment. This concept, also called Maslow's Theory of Needs, was introduced by Maslow (1943). Often outlined in a shape of a pyramid, it consists of a five-tier hierarchy of human needs, where basic needs are represented at the bottom and self-fulfillment needs are at the top of the pyramid (Figure A.2). The theory suggests that after existential and physical needs are met, people can work towards meeting higher-level needs.

Maslow's theory can be used to explain differences between consumption patterns in developing and developed countries. It is assumed that every person is capable and wants to move up towards self-actualization. However, as the theory implies, self-actualization is dependent on firstly satisfying basic needs (e.g. physiological and safety ones). That is why in developing countries, where the resources are scarce, we might expect that people will be primarily focusing on meeting their physiological needs, like getting enough food and water. Thus, if their income increases, they would probably opt for increasing their consumption of animal products. Only after they accumulate enough resources (e.g. wealth, information), they have the freedom to choose and to take into account the impacts of their decisions.

Factors of diets: focused on income

Global food systems are influenced by major demographic and economic transitions (Kovljenic and Savic 2017). The effect of income is not always straightforward, though, and depends on the category of food as well as the development of the country being analysed (Muhammad et al. 2017). Fransen (2011) shows that income is positively associated with demand for meat. Their analysis on income elasticity for beef indicates that while being positive, the elasticity varies from lower than one (for developed countries, where the demand for beef is less sensitive to income changes) to higher than one (for developing countries).

It can be expected that as income increases, changes in the share of animal FS and protein will not follow the same path for developed and developing countries. Analogically to Fransen (2011), we might suspect that developing countries will experience increases in the share of animal FS and protein as their income grows. In case of developed countries, the share of animal FS and protein is likely to be unaffected by the rise in income or it might even start decreasing.

Still, empirical studies typically assume a non-linear (semi-log, log-log) relationship between demand for a food product and income, which facilitates the estimation of income elasticity of demand (Fransen 2011). However, it is reasonable to expect that changes in income do not always result in constant or monotonous (just positive or just negative) changes in demand (and hence in environmental burden). On the other hand, our hypothesis is that the sign of these changes might vary depending on the income level and that it might resemble the Environmental Kuzents Curve (EKC)[1].

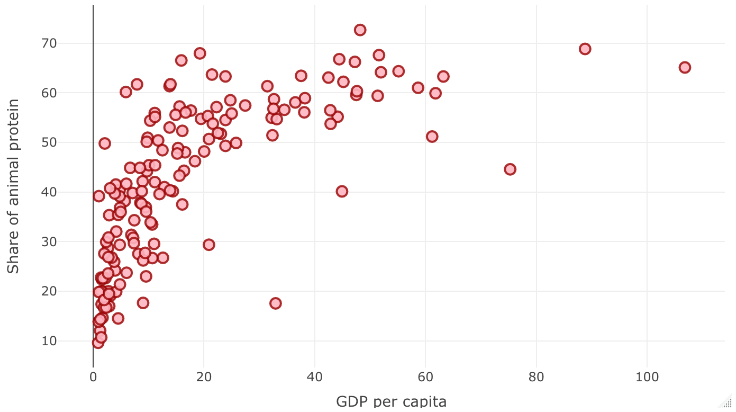

Figure 2: The relationship between GDP per capita (mean for each country) and the share of animal protein (in percentage).

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[1] EKC is a concept that was firstly introduced by Grossman and Krueger (1992) as an elaboration of the Kuznets Curve, which emerged in mid 50's. According to Kuznets (1984), at the early stages of development, as income rises, income inequality also increases. However, there is a point in the level of income after which increases in income lead to a decrease in income inequality. Grossman and Krueger (1992) extended this concept to cover environmental issues by studying the relationship between air quality and economic growth. The EKC hypothesis states that environmental quality is likely to get worse as the economy grows until a certain point in its development is reached (point of inflection), after which that environmental quality will start to improve again. Figure A.3 depicts this relationship, which is shaped as an inverted U (or a concave parabola). The goal of this paper is to verify, whether this relationship can be found between GDP per capita and the share of animal FS and protein.

Figure 2 depicts how the share of animal protein in human diet changes as GDP per capita grows. The scatter plot resembles a concave parabola and it indicates that there might be a turning point at some level of income, after which additional increases in income lead to a lower share of animal protein.

Nonetheless, it might be expected that different geographical regions might follow a different path. It is likely that there are geographical and cultural differences that could not be taken into account in our general analyses due to unavailability of data. To take into consideration geographical differences, continental regression is carried out for the continents consisting of more than 25 countries. Continents containing many developed countries might confirm the inverse U-shaped relationship because there would be enough data alongside the different levels of GDP. In contrast, continents with many developing countries (e.g. Africa) might not suggest that such a relationship exists so far. If there are not enough higher-income countries that would show the decreasing trend for the share of animal protein, the EKC hypothesis might not be supported.

Moreover, climate change affects negatively food security due to changing precipitation patterns and greater frequency and duration of extreme events, such as droughts, fires, or floods. Not only have yields in lower-latitude regions been adversely influenced by rising temperature but also livestock productivity is projected to be reduced, e.g. in drylands (IPCC 2019). Changes in animal production might consequently lead to changes in animal consumption, hence livestock units per capita are included in our model and considered as a proxy for animal food products availability. Changing temperature might also affect our food intake and the choice of food products in our diet. Figure 4 shows that there might be likely a negative association between the average annual temperature and the share of animal FS.

4 Empirical model

4.1 Data

The dataset used in this paper contains annual data for 178 countries[2] for the period 2000-2018. Values for macronutrient composition of diets together with other variables related to food supply were provided by FAO (2021). The Climate Change Knowledge Portal (CCKP 2021) was used to extract temperature data, health and food stability indicators were obtained from NCD Risk Factor Collaboration (NCD-RisC 2021) and the rest of the explanatory variables were obtained from the general UN database and from the OECD (2021) database.

Macronutrients

The data for the macronutrient composition of diets were extracted from Food and Agriculture Organisation of the United Nations's Food Balance Sheets (FBS).[3] In this paper,

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[2] Our sample consists of countries for which both FAO (2021) and UN (2021) collect data. The full list of countries can be found in Appendix C.

[3] FBS are comprised of food items, providing data on food sources of supply and utilization from 1961 until 2018. The FBS methodology changed a few years ago (from 2014), where the main difference is how imputations for FBS are treated. The new methodology generates dedicated modules for the data that are not provided by countries, and by applying a balancing mechanism, the imbalances are spread out proportionally among all the components (FAO 2021).

food supply, protein supply, and fat supply are analyzed, which all approximate the energy or macronutrient intake from a macroeconomic perspective (i.e. long-term trends in dietary patterns on a population level). We acknowledge the disadvantage of this approach since dietary energy supply and supply of protein and fat present a rough approximation to what was actually consumed. On the other hand, using supply data will facilitate the inclusion of many countries worldwide and the performance of global analysis, where geographical and temporal differences can be addressed.

Food supply for a specific period is defined as "the total amount of foodstuffs produced in a country added to the total quantity imported and adjusted to any change in stocks that might have occurred since the beginning of the reference period" (FAO 2021) and is expressed in kcal/capita/day (converted from g/capita/day). Animal and vegetal sources are differentiated for each category, which allowed us to create new variables, such as the share of animal-based protein ($P.A_{share}$) and the share of overall food supply coming from animal sources ($FS.A_{share}$). The variables were computed by dividing supply quantity from animal sources by total supply quantity (protein and food intake in total), hence, the created variables range from 0 to 1.

Summary statistics for selected macronutrient variables used in the model can be seen in Table 1. The minimum value for total food supply is 1729 kcal, which was the average total food supply for a person from Central African Republic in 2015. On the other hand, the maximum FS_{total} is 3885 kcal and it equals to the total food supplied for a person from Ireland in 2018. Mean and median values are 2782 and 2791, respectively, and the standard deviation is 460.49. There is also a great variation in animal food supply, which can be seen by both the absolute and relative values. Minimum value for animal food supply was 49 kcal/capita/day, while the maximum value was 1651. Similarly, the share of animal food supply ranged from 2.5% to almost 45.7%.

Table 1: Summary statistics for macronutrient, 2000-2018.

	min	max	median	mean	sd	n
FS_{total}	1729	3885	2782	2791	460.49	3320
$FS.A_{kcal}$	49.0	1651.0	515.0	543.6	329.67	3320
$FS.A_{share}$	2.439	45.685	18.531	18.501	9.528	3320
P_{total}	134.5	584.5	316.3	316.8	81.2	3320
P_{share}	6.446	17.925	11.302	11.230	1.519	3320
$P.A_{kcal}$	14.72	421.24	134.70	143.46	81.06	3320
$P.A_{share}$	6.745	75.021	42.990	42.279	16.368	3320

Note: FS_{total} stands for total food supply (kcal/capita/day), $FS.A_{kcal}$ denotes animal food supply in kcal/capita/day, $FS.A_{share}$ corresponds to the share of animal food supply (%), P_{total} is total protein supply (kcal/capita/day), P_{share} denotes the share of proteins (%), $P.A_{kcal}$ stands for animal protein expressed in kcal/capita/day and $P.A_{share}$ stands for the share of animal-based protein in the diet (%).

The average protein supply was around 316.8 kcal/capita/day with standard deviation of 81.2. In relative terms, both mean and median values are approximately at 11%, ranging from 6.4 to 17.9%. The amount of animal protein varies a lot around the globe, with the minimum of 14.7 (Rwanda, 2000) up to 421.2 kcal/capita/day (Iceland, 2017). The mean value is around 143.5 with standard deviation of 81.1. The minimum value for the share of animal protein is equal to $6,745\%$, meaning that only $6,745\%$ of protein was derived from animal sources. This value corresponds to an average daily share of animal-based protein for a Malawi person in 2002. In contrast, the highest value equals to 75%, meaning that as much as 75% of protein was obtained from animal sources. This value was estimated for an average Icelandic person in 2003. The mean value is equal to 42% and the standard deviation is at 16%.

Explanatory variables

Data for GDP per capita, retrieved from UN (2021), are expressed in international dollars (real prices) and adjusted for purchasing power parity (PPP).[4] To control for potential omitting-variable bias, socio-demographic variables, such as education (below upper-secondary (edu_{BUSRY}), upper-secondary (edu_{USRY}) and tertiary (edu_{TRY})) and type of residence (urban/rural); health-related variables (obesity and underweight in adult population, 18 years and older) and environment-related variables, such as temperature ($temp$)) and livestock units per capita (($LSU.cap$), are included in the model. The prevalence of obesity (or underweight) is measured as the total number of people with body mass index higher or equal than 30 kg/m^2 (or lower than 18.5 kg/m^2) during one year. These variables can only be controlled for the period 2000-2016 since data from 2016 were the most up-to-date data from NCD-RisC (2021), a network of health scientists providing rigorous world-wide data on risk factors for NCDs.

Summary statistics for all these variables are reported in Table 2. GDP per capita is ranging from only \$478.3 to \$116,786.5, with the mean at \$15,727.1 (both adjusted for PPP), and the lowest value recorded in Mozambique in 2000 and the highest one in Luxembourg in 2018. Overall, 413 out of 3,320 observations are missing since GDP in those cases failed to be captured.

Table 2: Summary statistics for explanatory variables, 2000-2018.

	min	max	median	mean	sd	NA
GDP	478.3	116,786.5	9,791	15,727.1	16,845.91	413
$urban$	13.28	102.61	57.25	56.77	22.15	0
edu_{BUSRY}	6.56	80.63	25.28	31.48	19.20	2717
edu_{TRY}	5.06	57.89	28.73	28.23	11.01	2712
$obese$	0.66	52.84	16.44	17.52	9.16	511
$under$	0.23	29.15	5.90	3.19	5.68	511
$temp$	-5.05	29.38	19.02	22.52	8.17	207
$LSU.cap$	0.007	3.700	0.340	0.224	0.434	44

Note: GDP per capita is expressed in international dollars and adjusted for PPP, urban population, education, obesity, and underweight are expressed in percentages, the temperature is in degrees Celsius and *LSU.cap* in livestock units per capita.

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[4] Gross Domestic Product (GDP) can be seen as an approximation for the development of a country, which is believed to have an impact on the amount of animal-based food products in the diet. The idea behind PPP is that the nominal GDP is converted into a value that is more easily comparable between countries that have different currencies so the relative cost of living is taken into account. It is often used in macroeconomic analyses because it allows for comparing economic productivity together with standards of living among countries since it is based on a ”basket of goods” approach, and consequently, it provides a better idea of the real disparities in income (Investopedia 2021).

Figure 3 displays the correlation coefficient, ρ, among all key variables used in our models. As expected, there is a high correlation between the amount (and the share) of animal food supply and total food supply. The same holds for animal proteins. Moreover, almost all independent variables (except for livestock units per capita) are fairly correlated with the dependent variables ($\rho > 0.5$).

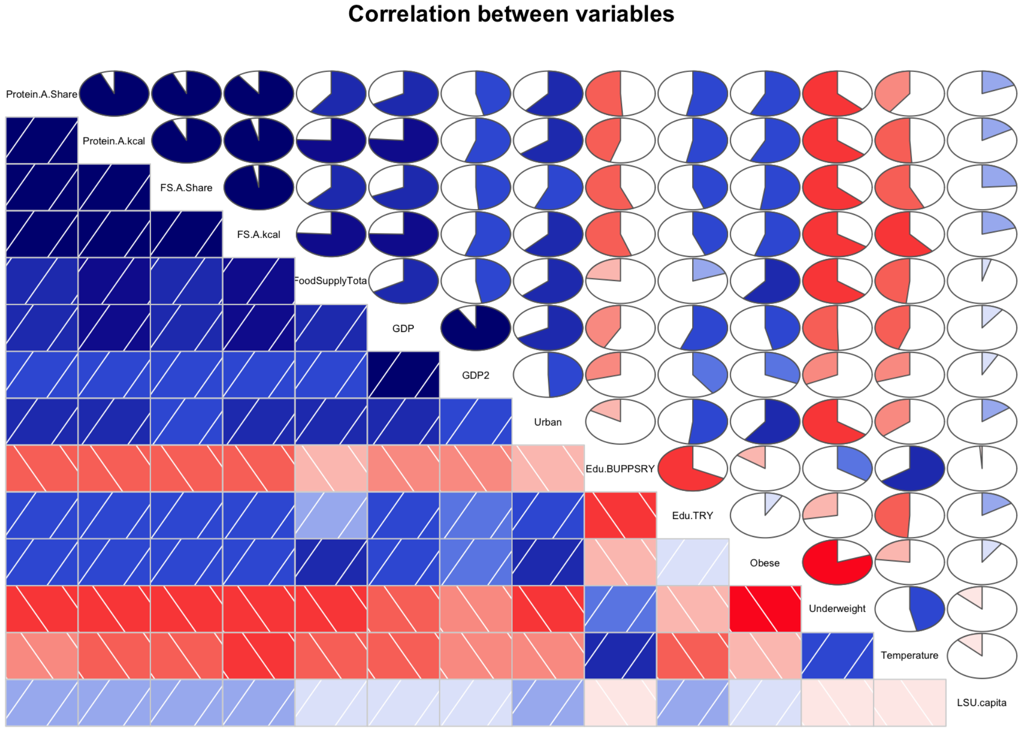

Figure 3: Correlogram

Note: Blue color indicates a positive relationship while red stands for a negative correlation. The intensity of the color denotes the strength of the correlation, which is more precisely displayed in the upper triangle part of the correlogram, where small pie charts show how strong the correlation is.

Analysing the correlation between the explanatory variables might help detecting the problem of multi-collinearity. All the values of variance inflation factor[5] (VIF) (presented in Table B.4) are below 10, which is often a cut-off value, implying multicollinearity should not be present.

4.2 Panel data model

Panel data represent a multi-dimensional data that take into consideration measurements over time (Wooldridge 2013). Essentially, the same individuals are followed across a certain period of time. Given that, unobserved characteristics of individuals may be present, which

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[5] VIF is one of the common statistics allowing to uncover how severe the problem of multicollinearity is. Higher values of VIF would result in higher values of the variance of the β estimates. For $VIF \geq 10$, multicollinearity may pose a problem (Wooldridge 2013). VIF, as other similar statistics, can be misused since it is extremely difficult to specify how much correlation among independent variables is too much.

implies utilizing appropriate models to account for the unobserved effect. In our case, let us define the basic unobserved effects model, i.e. fixed effects model, as follows:

$$y_{it} = \beta_0 + \beta_1^T X_{it} + c_i + u_{it}, \quad \text{where } u_{it} \sim \mathcal{N}(0, \sigma^2), \tag{1}$$

where $i = 1, \ldots, N$ denotes countries and $t = 1, \ldots, T$ denotes time periods, i.e. years.

The dependent variable (y_{it}) is defined as the total food supply in kcal/capita/day and it measures i) animal food supply ($FS.A_{kcal}$), ii) animal-based protein ($P.A_{kcal}$), or iii) total proteins (P_{total}). Alternatively, our dependent variable is also defined as a relative measure, describing i) the share of animal food supply ($FS.A_{share}$), ii) the share of animal-based proteins ($P.A_{share}$), or iii) the share of total proteins (P_{share}), yielding, in total, six (uncorrelated) dependent variables. The term X_{it} is a vector of K explanatory variables that includes GDP per capita (GDP_{it}), overall food supply (FS_{it}), share of population living in urban areas ($Urban_{it}$), prevalence of obesity ($Obese_{it}$) and underweight ($Under_{it}$), average annual outdoor temperature ($Temp_{it}$), and in case of total protein analysis, also livestock units per capita ($LSU.cap_{it}$). The variable c_i captures all unobserved time-constant factors and country-specific factors that do not change across countries and over time, respectively. The last term u_{it} is idiosyncratic error. The coefficients β_0 and a vector β_1 are estimated. The main hypothesis in this paper is that as countries get wealthier, they can afford to spend more on food, which might result in a higher diversity of food products and higher intakes of protein. When estimating the model for the amount of protein in the diet, livestock per capita is also taken into consideration, since the more livestock (which can be loosely translated as higher accessibility to livestock products, hence, the source of protein), the higher intake of protein. Relationships between all explanatory variables and protein intake (in kcal) are plotted in Figure A.5.

Our panel is unbalanced and consists of 178 countries and 19 time periods. Since the potential sources of biases are still limited compared to OLS (Collischon and Eberl 2020), the FE estimation is employed.[6,7]

Our main goal is to test whether the EKC hypothesis holds in the case of animal food supply and protein. First, Figure 4 displays the relationship between GDP per capita and the share of animal food supply. In the left graph, all data points, conditional on the average yearly temperature (colour) and the overall food supply (size of the dots), are plotted.

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[6] When independent variables are strictly exogenous, meaning that for each time period, the idiosyncratic errors are not correlated with independent variables, pooled ordinary least squares (pooled OLS) is employed. However, this is not very common for many panel data sets and c_i should be treated as a random variable. If c_i is correlated with any of the independent variables, then x_{itj} will be correlated with the composite error $v_{it} = c_i + u_{it}$ leading to biased and inconsistent estimates when using pooled OLS. This problem can be solved by using Fixed Effects (FE) estimation. It allows for arbitrary correlation between c_i and independent variables in any time period. On the other hand, because of the FE transformation, any independent variable that is constant over time for all i disappears, as well. Another disadvantage is losing one degree of freedom in each cross-sectional observation i because of the time-demeaning, resulting in $N(T-1) - K$ degrees of freedom. Also, Collischon and Eberl (2020) argue that in some applications, there might be concerns about unobserved time-varying heterogeneity, which could lead to omitted variable bias, however, this holds true for many standard methods, such as pooled OLS or First Differences (FD).

[7] The Breusch-Pagan (BP) Lagrange Multiplier test for random effects is performed to decide between RE and pooled OLS regression, whilst the F Test is run to decide on Individual and Time fixed effects based on the comparison of FE and pooled OLS. The Hausman test decides between FE and RE models. The Breusch-Pagan test and Breusch–Godfrey test for panel models are used to detect whether our model suffers from the violation of the homoskedasticity assumption and serial correlation. In the case the null hypothesis is rejected, the regression with robust SE is performed.

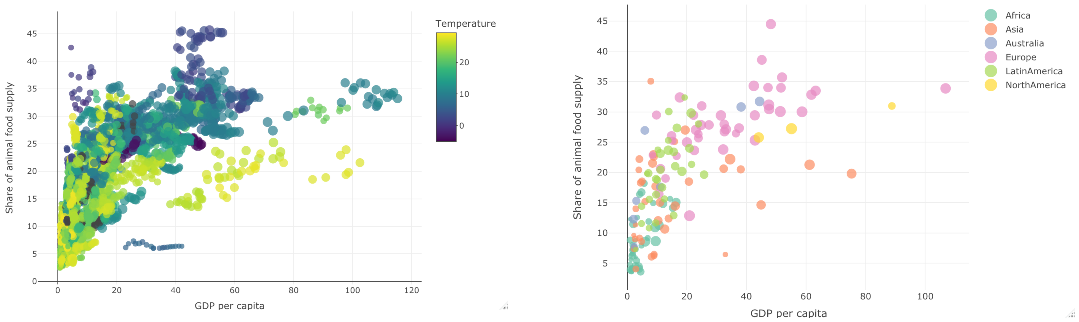

Figure 4: The relationship between GDP per capita and the share of animal food supply, by temperature (left) and continents (right).

Generally, we can note an increasing tendency for the share of animal food supply in relation to GDP per capita, which looks quite strong for the lower values of GDP. It seems to slow down, or even reverse, after a certain point of GDP per capita is reached. Plotting country averages, the graph on the right focuses on continental differences (distinguished by colour). In particular, countries in Latin America could be approximated by a linear line, whereas the countries from Europe seem to follow a curve of a concave parabola. That being said, the graphs only show possible associations, which will be further tested for in our regression analyses.

Figure 5 shows the relationship between GDP per capita and the share of animal protein approximated by a quadratic function[8]. The interpolation shows that firstly, the share of animal protein increases as GDP per capita rises. After a certain level of GDP, this share tends to decrease, however, the confidence intervals are wider (as we do not have many data available for higher values of GDP per capita).

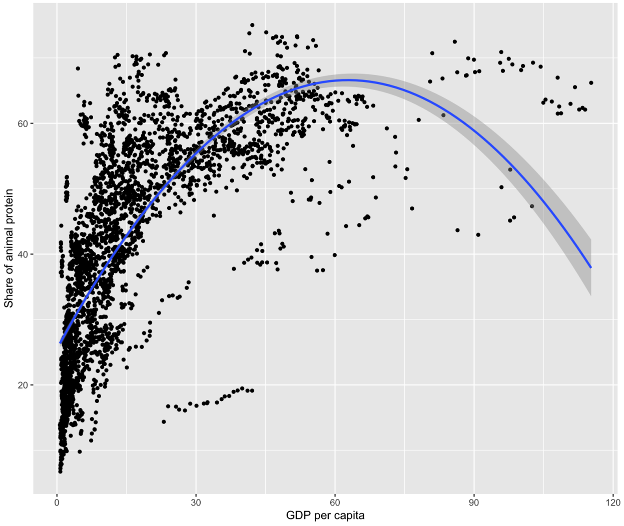

Figure 5: The relationship between GDP per capita and the share of animal protein (%), approximated by the quadratic function.

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[8] The relationship between GDP per capita and the share of animal protein conditional on temperature or continents is displayed in Appendix A (Figure A.6).

The quadratic specification of the EKC model is used to test our hypotheses, specifically, to explain the amount and the share of animal-based food supply ($FS.A.kcal$ and $FS.A.Share$) and the amount and the share of animal-based proteins ($P.A.kcal$ and $P.A.Share$) globally[9], and for the Member States of the European Union[10]. A short version of the EKC model (including only GDP and GDP^2) is applied for specific continents (Africa, Asia, Europe, Latin America) to examine a more precise shape of the curve[11]. As a robustness check, the log-log model is presented in Appendix D since this specification is commonly used in studies to derive the elasticity. For the sensitivity analysis, we estimate the log-log model for a group of countries with different income level to obtain the elasticity with respect to the share of animal food supply and animal proteins. Specifically, we estimate these models for four income levels (GDP quartiles) and for two sub-samples of countries having GDP per capita higher than \$50,000 (GDP50) and \$80,000 (GDP80), see Appendix D

5 Results

5.1 Descriptive analysis

Food supply, animal-based food and proteins over last 60 years

There has been a huge variation among the EU countries when it comes to the actual proportion as well as the direction of changes in the share of animal protein over time (Figure A.8). Taking yearly mean for all EU countries, a gradual increase from 1960 to 1990 can be notes, after which the rate of increase slowed down considerably. Countries with lower share of animal protein experienced a rapid increase in this share while for countries with already higher share of animal protein the increase was less subtle in the beginning. From 1980, some of them started to even decrease the share of animal protein. Figure A.9 shows an analogical graph, but for the share of animal food supply.

Moving on from the EU analysis, the global evaluation was carried out. In order to create easily readable graphs, yearly mean values of several macronutrient indicators for each continent were computed (Figure 6). First two graphs on the top show the evolution of total FS and protein (in kcal/capita/day). Within the last 60 years, all continents have been experiencing a gradual increase in the total food supply and protein. It can be noted that there was a sudden increase for North America in 2013, which is hard to explain and might be due to the changes in methodology. Two graphs in the middle show the share of animal FS and protein (in %). The data suggest that Asia and Africa have been experiencing a rise in those shares, while in North America, the share of animal-based FS and protein has been on decline in the past few years. However, looking at the absolute values (in kcal/capita/day), the amount of protein derived from animal sources (bottom right) has actually increased. This increasing trend in the energy we get from animal-based protein is present in all continents and is especially clear for Asia, Europe and Africa. Slow but steady increasing pattern in Asia and Latin America can be seen for the amount of animal FS, while it is stagnating for Europe and North America.

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[9] The sample consisting of all 178 countries, denoted *Global*.

[10] To better detect trends among countries that are fairly developed. Sample denoted EU.

[11] There might be geographical and cultural differences that could not be taken into account in general analyses due to the unavailability of data.

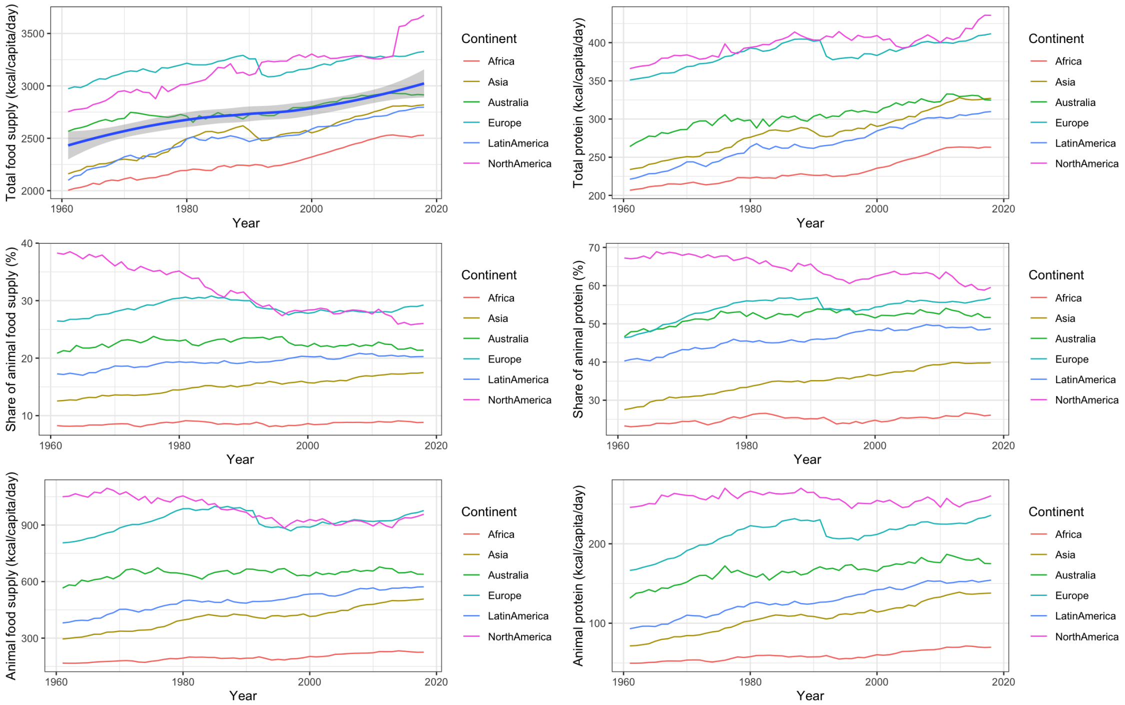

Figure 6: Long-run trends in total food and protein supply, animal-derived food and protein supply, and the energy derived from animal-based food and proteins, by Continent,1961-2018.

Note: The total food supply and total protein are in kcal/capita/day and are shown on the top, the share of animal-derived food supply and the share of animal-based protein out of the total dietary protein are measured in percentage points and are shown in the middle part, and the energy derived from animal sources and the energy derived from animal-based protein are reported in kcal/capita/day and shown on the lower part of the figure.

Macronutrient composition vs. GDP

Inspired by Perisse et al. (1969) study, where the authors evaluated the correlation between the percentage of calories provided by various nutrients and gross domestic product per head using 1962 data (based on 85 countries, Figure A.7), a graph showing macronutrient composition in relation to income per capita for 178 countries (based on 2018 data, Figure 7[12]) was created.

The visualisation using 2018 data shows similar trends as the graph by Perisse et al. (1969) (Figure A.7). As GDP per capita grows the share of carbohydrates decreases while the share of nutrients derived from the animal products (animal fat and animal protein) increases. The share of total carbohydrates for lower income countries seems to be generally lower in 2018 than in 1962, meaning that there is a higher proportion of fats and protein in our diets. The proportion of dietary protein was around 10% in 1962 and continues to be stable even now. The mean value of the share of protein in 2018 was $11,29\%$ and the median equaled to $10,98\%$. Summary statistics for the share of animal (P.A.Share) and vegetal (P.V.Share) protein are displayed in Table B.2 and mean values for certain macronutrient variables distinguished by continents are shown in Table B.3.

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[12] The logarithm of GDP per capita is used because it better approximates normal distribution. The conversion of values for log(GDP) (on the vertical axis in Figure 7) can be facilitated by looking at the summary statistics in Table B.1.

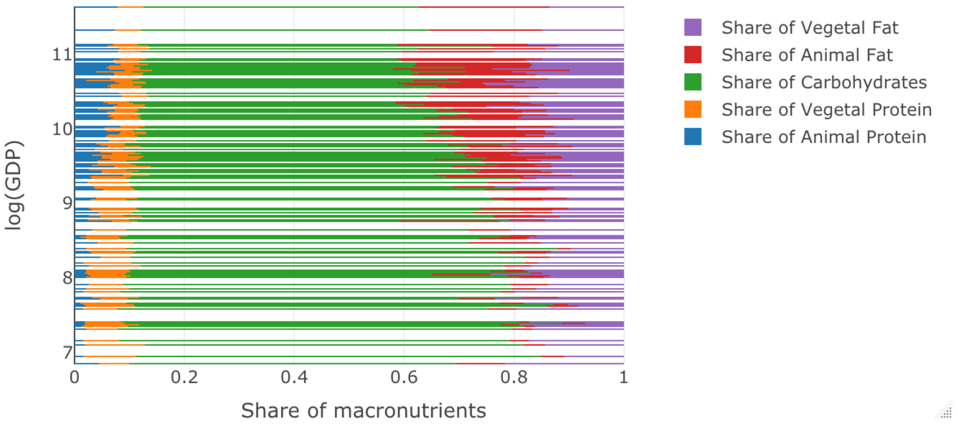

Figure 7: Macronutrient composition vs. log(GDP), for 178 countries, 2018

5.2 Regression results

In this section, the estimation results are presented. For each regression, `plmtest` function with both `individual` effects (which takes into account unobserved unit effects) and `twoways` effects (which tests for individual and time effects) was used. Using country and time effects resulted in some cases in slightly more significant coefficient estimates compared to a model with only country FE, however, generally, the results from different model specifications were consistent[13]. The resulting p-value of `plmtest` test was considerably smaller than the benchmark of 0.05[14], which implies that it makes sense to perform panel data analysis.

After performing the Breusch-Pagan test against heteroskedasticity and Breusch-Godfrey test for serial correlation, the null hypothesis of homoskedasticity was rejected in all cases. Hence, robust SE are reported in regression results shown in tables that were created using the package `stargazer` (Hlavac 2018). The results from Hausman test imply the use of FE, which is also a recommended method for aggregate data (Wooldridge 2013). We ran the regressions adjusting for either unit effects or both unit and time effects. The clustered SE are shown in parentheses.

Linear Model for Proteins

GDP per capita was not found to have a significant effect on the amount or the share of proteins in our diet (Table 3) even though the resulting income elasticity would be positive (with very low values). As expected, what influences these two variables the most is the total food supply. However, its effect is rather small. For example, increasing total FS by 10% leads to 0.1 kcal increase in proteins and around 0.009 percentage points increase in the share of proteins in our diet. For the EU countries, a slightly bigger impact was estimated. Specifically, the share of proteins is associated with 0.02 percentage points increase if total FS is increased by 10%. Another significant variable is livestock units per capita, which is positively associated with the amount of proteins. Again, the

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[13] The results from the model with country and time fixed effects can be found in Appendix D.

[14] The level of significance, α, is set to be 0.05. When p-value$< \alpha = 0.05$, the null hypothesis is rejected. When p-value$\geq \alpha = 0.05$, we cannot reject the null hypothesis.

resulting effect is rather small. In the global estimations, the prevalence of obesity seems to positively influence both the amount and the share of proteins. It is assumed that higher prevalence of obesity is associated with higher food intake, so consequently, we would expect higher intake of proteins. Nevertheless, it might not be as unambiguous (because of the double burden of malnutrition) and there might be other important factors. In the EU regression, obesity is insignificant. Generally, the rest of the variables do not exhibit any significant effects on the dependent variables.

Table 3: Lin-log Model: The amount and the share of proteins in the diet at the Global level and for the EU. FE estimation using robust SE is presented.

	Global				*EU*			
	Proteins.kcal		Proteins.Share		Proteins.kcal		Proteins.Share	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(GDP)	0.014	0.017	0.014	0.018	0.051**	0.038	0.051	0.046
	(0.013)	(0.014)	(0.014)	(0.014)	(0.021)	(0.025)	(0.033)	(0.034)
log(FS)	1.061***	1.057***	0.088**	0.078*	1.136***	1.129***	0.230***	0.223***
	(0.042)	(0.041)	(0.043)	(0.042)	(0.068)	(0.068)	(0.076)	(0.082)
log(Urban)	−0.032	−0.044	−0.040	−0.060	0.024	0.112	0.259	0.305
	(0.042)	(0.046)	(0.044)	(0.048)	(0.154)	(0.186)	(0.191)	(0.231)
log(Obese)	0.060**	0.076**	0.069***	0.095***	0.073	−0.068	−0.123	−0.208
	(0.025)	(0.036)	(0.026)	(0.034)	(0.161)	(0.186)	(0.178)	(0.242)
log(Under)	0.030	0.005	0.045	−0.001	0.012	0.083	−0.059	−0.043
	(0.031)	(0.045)	(0.029)	(0.045)	(0.150)	(0.150)	(0.172)	(0.178)
Temp	−0.001	−0.001	−0.002	−0.001	0.002	0.002	0.002	0.0003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)
log(LSU.cap)	0.037**	0.034**			0.165***	0.174***		
	(0.015)	(0.016)			(0.035)	(0.035)		
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2,545	2,545	2,576	2,576	459	459	459	459
R^2	0.758	0.664	0.114	0.067	0.653	0.637	0.095	0.083
Adjusted R^2	0.742	0.640	0.055	−0.001	0.626	0.594	0.027	−0.024
Note:								*p<0.1; **p<0.05; ***p<0.01

EKC Model for Animal Food Supply

The results for the EKC model for animal FS are presented in Table 4. This model includes GDP per capita and its square term as well as temperature and its square. All of these variables were found to be significant for both the amount and the share of animal FS (global estimation). It is interesting to see that the sign for GDP and temperature is positive while the sign of their square terms is negative.

Since the regression contains a quadratic GDP term, which is significant, the effect of GDP on the regressand will be dependent on the initial value of GDP. The change of \$10,000 will be different for a country going from \$10,000 to \$20,000 than for a country going from \$90,000 to \$100,000. Equation 2 shows how the effect of GDP on the share of animal FS is derived. To interpret the results, analogical derivation is used for the remaining variables.

$$\frac{\delta FS.A.Share}{\delta GDP} = \beta_1 + 2\beta_2 GDP \tag{2}$$

Table 5 shows a few estimations for each regression. In addition to that, a turning point was computed by setting the derivative from Equation 2 equal to 0. The global turning point is equal to \$85,510 and \$81,685 for the amount and the share of animal FS

Table 4: Estimation results: EKC Model for animal-based food supply in kcal and as the share. Country FE estimation using robust SE.

	Global		EU	
	FS.A.kcal	FS.A.Share	FS.A.kcal	FS.A.Share
GDP	9.639***	0.248***	10.262***	0.327***
	(1.337)	(0.046)	(2.792)	(0.091)
GDP2	−0.056***	−0.002***	−0.075***	−0.002***
	(0.011)	(0.0004)	(0.022)	(0.001)
FS	0.225***	0.002*	0.334***	0.002
	(0.029)	(0.001)	(0.102)	(0.003)
Temp	12.794***	0.412***	22.940**	0.684**
	(4.673)	(0.146)	(11.282)	(0.339)
Temp2	−0.323**	−0.011**	−0.639	−0.020
	(0.138)	(0.005)	(0.562)	(0.018)
Urban	0.363	0.013	5.512	0.166
	(1.179)	(0.044)	(4.234)	(0.134)
log(Obese)	−6.888	1.565*	−107.597	−2.757
	(25.677)	(0.912)	(332.648)	(9.298)
log(Under)	53.524	2.954***	91.069	3.192
	(33.059)	(1.142)	(289.068)	(8.290)
Observations	2,576	2,576	459	459
R^2	0.411	0.139	0.336	0.143
Adjusted R^2	0.372	0.081	0.283	0.075
Note:			*p<0.1; **p<0.05; ***p<0.01	

respectively. It means that until this amount is reached, increases in GDP will result in higher amount and share of animal FS. As we get closer to $85,510 (or $81,685), the effect will diminish, until it reaches 0 at the respective turning point. Moving from this value higher, the association between GDP and the amount or the share of animal FS will be negative. To put it another way, for very wealthy countries (having GDP$>$ $85, 510 or GDP$>$ $81, 685), increasing GDP would induce a decrease in the amount or the share of animal protein. For the EU countries, this turning point was estimated to be $68,583 and $69,219 respectively.

Table 5: The effect of GDP per capita on the amount and the share of animal food supply derived from the EKC model as in Table 4.

	Global		EU	
	FS.A.kcal	FS.A.Share	FS.A.kcal	FS.A.Share
from 10,000 to 20,000	85.11	2.18	87.65	2.80
from 90,000 to 100,000	-5.06	-0.25	-32.05	-0.98
turning point	85,510	81,685	68,583	69,219

Table 5 displays the effect of GDP per capita on regressands from Table 4. Global estimation suggests that increasing GDP per capita from $10,000 to $20,000 adjusted for PPP will lead to a 85.11 kcal increase in animal FS and a 2.18 percentage point increase in the share of animal FS. On the other hand, increasing GDP by $10,000 but from $90,000 to $100,000 will on average result in 5.06 kcal drop in animal FS and the share of animal FS is estimated to decrease by 0.25 percentage points.

In addition to the regression results, income elasticity was derived from our estimation (derivation in subsection D.3). The graph using Equation 4 was created (Figure 8).

Estimated income elasticity is positive for lower-income countries, however, it becomes negative once it reaches a certain value of GDP. The maximum value for elasticity and the intersection points were computed within the domain indicated by our data. The maximum is equal to 0.29, which happens at $33,977 of GDP per capita. The elasticity turns to be negative at $81,725 of GDP per capita, though it is still inelastic within the domain for GDP. These values can be compared with the income elasticity from the log-log regression for the share of animal FS (Appendix D). On top of the global and EU estimations, sensitivity analysis was conducted by dividing the countries into several groups (quartiles) based on their income. The goal was to estimate the income elasticity for each income group to check whether it is similar to the estimated elasticity from the EKC analysis (findings available in Appendix D).

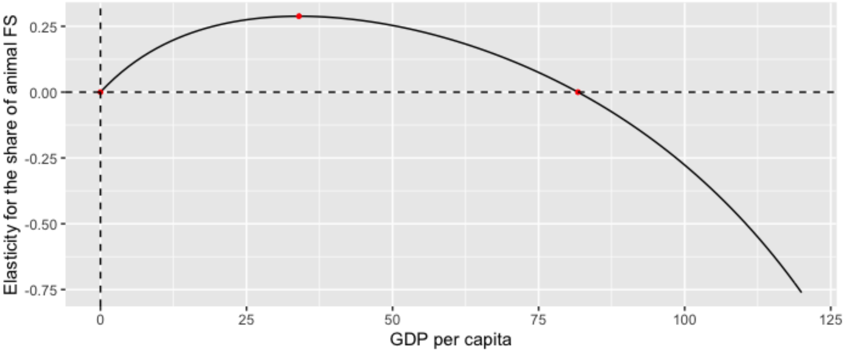

Figure 8: Estimated income elasticity for the share of animal food supply. GDP per capita expressed in thousands USD adjusted for PPP.

In global estimations, the turning point for temperature in relation to the amount of animal FS was estimated to be 19.8, and to the share of animal FS 18.6 degrees Celsius. In the EU estimations, the square term for temperature is not significant, implying that increases in temperature will on average lead to increases in the amount or the share of animal FS. Globally, total FS seems to play some role in how many animal products we consume, too. Surprisingly, underweight was found to be positively associated with the share of animal FS. Other variables did not result to be significant.

EKC Model for Animal Proteins

The results for the EKC model for animal protein are presented in Table 6. Again, GDP per capita and its square are estimated to have a significant impact on the respective dependent variables in all cases presented. In contrast, temperature is not significant in relation to animal protein. Another significant variable is total food supply, which shows to have a positive effect on the amount of animal protein both globally and on the EU level. In the EU case, the percentage of urban population seems to be positively associated with the amount of animal protein in the diet. Surprisingly, the prevalence of obese people was found to have a negative effect on the share of animal protein. Because of the use of aggregate data, it does not mean that when somebody is obese, the person would have lower share of animal protein. It can be interpreted that countries with higher prevalence of obese people[15] are associated with lower share of animal protein.

Table 6: Estimation results: EKC model for animal proteins in kcal and as the share. Country FE estimation using robust SE.

	Global		EU	
	P.A.kcal	P.A.Share	P.A.kcal	P.A.Share
GDP	2.423^{***}	0.503^{***}	3.291^{***}	0.679^{***}
	(0.491)	(0.095)	(1.061)	(0.167)
GDP2	-0.013^{***}	-0.003^{***}	-0.020^{**}	-0.005^{***}
	(0.004)	(0.001)	(0.008)	(0.001)
FS	0.062^{***}	0.003	0.086^{***}	0.0002
	(0.008)	(0.002)	(0.021)	(0.006)
Temp	0.814	0.085	2.827	0.225
	(1.073)	(0.199)	(2.482)	(0.383)
Temp2	−0.028	−0.004	−0.114	−0.013
	(0.034)	(0.007)	(0.116)	(0.022)
Urban	−0.039	0.027	2.174^{**}	0.272
	(0.328)	(0.079)	(1.019)	(0.169)
log(Obese)	−4.279	2.122	−129.948	-21.504^{**}
	(6.788)	(1.673)	(79.321)	(10.273)
log(Under)	2.756	2.960	−65.796	−10.937
	(9.558)	(1.937)	(71.513)	(10.030)
Observations	2,576	2,576	459	459
R^2	0.426	0.171	0.380	0.245
Adjusted R^2	0.388	0.116	0.330	0.185

Note: *p<0.1; **p<0.05; ***p<0.01

In Table 7, the effect of GDP for specific values of GDP and the estimated turning point are displayed. Computed turning points are higher than the ones from the EKC models for animal FS. For example, turning point for GDP in relation to the share of animal protein is equal to \$81,460. Increasing GDP from \$10,000 to \$20,000 will lead to the increase of the share of animal protein by 4.41 percentage points. On the other hand, increasing GDP from \$90,000 to \$100,000 will on average decrease the share of animal protein by 0.53 percentage points.

Table 7: The effect of GDP per capita on the amount and the share of animal protein derived from the EKC model as in Table 6.

	Global		EU	
	P.A.kcal	P.A.Share	P.A.kcal	P.A.Share
from 10,000 to 20,000	21.67	4.41	29.00	5.83
from 90,000 to 100,000	1.21	-0.53	-2.32	-1.85
turning point	94,732	81,460	84.075	70,729

Figure 9 shows that the elasticity is positive (inelastic) for GDP per capita from 0 to \$77,280. The maximum elasticity (0.25) is reached at \$33.197. From \$77,280, the income elasticity is negative and it stays inelastic within our domain. These values can be compared with the income elasticity from the log-log regression for the share of animal protein (subsection D.4).

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[15] Because of a double burden of malnutrition, low-income countries might also experience high levels of obesity.

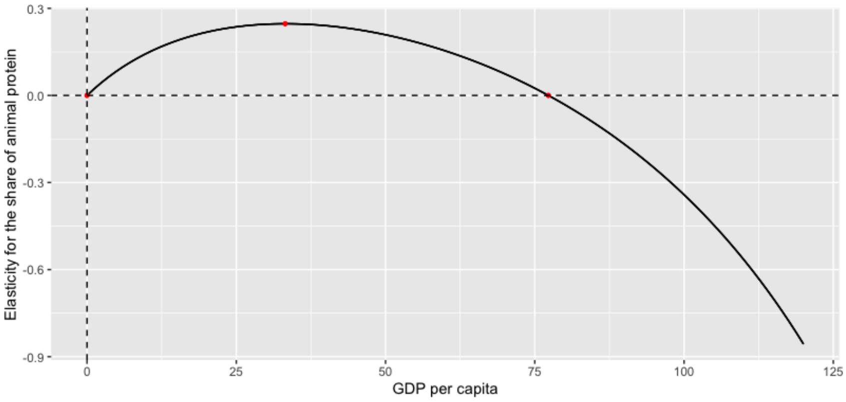

Figure 9: Estimated income elasticity for the share of animal protein. GDP per capita expressed in thousands USD adjusted for PPP.

EKC model for continents

To check the robustness of our results, a continental analysis was conducted to examine whether the inverted U-shaped curve is present not only globally but also whether the EKC hypothesis holds for specific continents[16]. The simple version of the EKC model (contianing GDP per capita and its square) was therefore carried out on the sample for Europe, Asia, Latin America and Africa. The motivation was to differentiate between these high-level geographical regions because of their cultural differences that could not be included in the global models and see whether there are continents that might experience different evolution of the share of animal FS or protein.

The results can be seen in Table 8 in Panel A and B. In both cases (share of animal FS and protein), GDP and GDP^2 are significant only in Europe and Asia. Here, the relationship is consistent with the findings from global and EU regressions. It seems that the change of the slope is steeper for Europe (-0.003 for the share of animal FS and -0.006 for the share of protein) compared to Asia (-0.002 and -0.005 respectively), and consequently, it will take longer for Asia to surpass a turning point. In Europe, the change of GDP having a negative impact on the share of animal FS is estimated to happen for a lower value of GDP. Specifically, the turning point for Europe and Asia is \$64,774 and \$91,338 for the share of animal FS and \$57,283 and \$90,404 for the share of animal protein. After surpassing the respective values, the share of animal FS and protein are estimated to decrease.

In contrast, the results for Latin America and Africa do not imply a quadratic relationship between GDP per capita and the share of animal FS or protein. In fact, neither GDP nor GDP^2 result to be significant. This means that there are other factors that influence the share of animal FS or protein. Moreover, the adjusted R^2 from these regressions are negative so the model contains terms that do not help to predict the response variable.

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[16] The continents were chosen based on the availability of data, or else, having enough observations to derive reliable results.

Table 8: Estimation results: EKC model for continents for the share of animal food supply (Panel A) and animal-based proteins (Panel B). FE estimation with robust SE.

Panel A

	Dependent variable: FS.A.Share			
	Europe	Asia	Latin America	Africa
GDP	0.330***	0.407***	0.061	0.174
	(0.062)	(0.092)	(0.297)	(0.341)
GDP2	−0.003***	−0.002***	0.002	0.001
	(0.001)	(0.001)	(0.007)	(0.012)
Observations	767	701	570	792
R^2	0.160	0.222	0.040	0.023
Adjusted R^2	0.112	0.177	−0.015	−0.035
Note:				*p<0.1; **p<0.05; ***p<0.01

Panel B

	Dependent variable: P.A.Share			
	Europe	Asia	Latin America	Africa
GDP	0.666***	0.831***	0.334	0.745
	(0.098)	(0.151)	(0.434)	(0.757)
GDP2	−0.006***	−0.005***	−0.003	−0.006
	(0.001)	(0.001)	(0.011)	(0.025)
Observations	767	701	570	792
R^2	0.270	0.294	0.044	0.039
Adjusted R^2	0.227	0.254	−0.011	−0.018
Note:				*p<0.1; **p<0.05; ***p<0.01

6 Discussion

Analysing macronutrient composition in relation to GDP per capita (shown in Figure 7) revealed that higher values of GDP per capita might be associated with larger shares of animal-based protein and fats in the diet. To properly investigate the relationship between income per capita and both the amount and the share of animal protein and FS in general, panel data regressions were conducted. Plotting the share of animal FS and protein as a function of GDP per capita, which is depicted in Figure 4 and Figure 5, suggested the inclusion of a quadratic term for GDP enables us to test the EKC hypothesis in this specific case.

In 1962, the proportion of dietary protein was around 10% (Figure A.7) irrespective of the level of GDP per capita and it continues to be stable even now, with mean of 11.29% and median of 10.98% in 2018 (Figure 7). This is also supported by results from the regression analysis, where GDP was not found to be significant in relation to the amount or the share of dietary protein (Table 3). The AMDR for protein is $10 - 35\%$ of total energy intake (Otten et al. 2006) so even though mean and median satisfy this condition, we checked how many countries are below the recommended value. In 2018, there were 35 countries with the share of dietary protein below 10%. The lowest shares were identified in Guinea-Bissau (7.76%), Liberia (7.89%) and Mozambique (8.07%). Still, the first 10 countries with the lowest value for the share of protein had GDP per capita below 7000$ so mainly low-income and middle-income countries experience this nutritional problem.

The following analyses aimed to test the EKC hypothesis, in particular, whether the relationship between GDP per capita and the share of animal FS and animal protein resemble the Environmental Kuznets Curve. Findings across both samples (Global and EU) are consistent suggesting that GDP as well as its square are significant. This means that the effect of GDP is dependent on the initial level of GDP. The global turning point is \$81,685 for the share of animal FS and \$81,460 for the share of animal protein. Until this amount is reached, increases in GDP are associated with increases in the share of animal FS (and protein). In contrast, countries with GDP greater than \$81,685 (or \$81,460) would experience on average a decrease in the share of animal FS (or animal protein) as their GDP increases. It might be due to health reasons, or the fact that people acknowledge the negative impact on the environment and they modify their consumption and dietary patterns. Analysing data from the EU countries, the turning point is estimated to be around \$69,219 and \$70,729 respectively.

Additionally, income elasticity from the quadratic estimation was calculated. This way, the resulting elasticity is not constant but varies for each country depending on their initial level of GDP per capita. Within the domain for GDP per capita, the elasticity is inelastic, shaped as a concave parabola, with the maximum of 0.29 at \$33,977 for the share of animal FS and 0.25 at \$33,197 for the share of animal protein. It is positive for lower-income countries; however, it becomes negative once it reaches approximately 81,000\$ and \$77,280 of GDP per capita, respectively. Fransen (2011) estimated income elasticities for beef, which resulted to be positive. However, they found strong differences in the size of income elasticity between religions, where the income elasticity in Atheistic countries was greater (0.5) than in Protestant countries (0.22) and countries with large Hindu (0.18) or Muslim populations (0.14). In comparison to their results, we found that income elasticity in relation to the share of animal FS or protein can get below zero after a certain level of GDP per capita. Having said that, our findings also show that this development is unique for each region. Even though globally, the inverted U-shaped curve is supported by the data we acquired, we acknowledge geographical and cultural differences that we could not take into account in our model because of the unavailability of data. For sensitivity analysis, the EKC regression was carried out for four different regions. It can be seen from Table 8 that the hypothesis of inverted U-shaped association holds for Europe and Asia (despite each region following a different curve). In Europe, the turning point was estimated to be \$64,773 for the share of animal FS and \$57,283 for the share of animal protein, while in Asia it was \$91,338 and \$90,405 respectively. On the other hand, data from Latin America and Africa indicate that the relationship between the variables is not that strong. Neither GDP nor GDP^2 are significant for these two continents. There are perhaps other factors, such as total food intake, that might be affecting the share of animal FS or protein there.

It could be expected that regional analysis would bring more heterogeneous results and that continents with a lot of developing countries will not support the EKC hypothesis because as Stern (2004) stated, including more low-income data points in the sample (as is the case of Asia) can lead to a higher turning point, which is one of his criticisms of the EKC. This might indicate that for us to have a general overview, it is useful to assess the global model, where the variation in GDP is larger and various stages of development are taken into account. The robust estimate might be an indicator for prospective development for countries around the globe. However, to have a more accurate picture of the regional development and forecasting, continental or country-level analyses are needed.

Another key factor with respect to animal FS was temperature (not significant for animal proteins). In the global analysis, temperature as well as its square were found to be significant, suggesting a relationship in a shape of concave parabola. The turning point was estimated to be 18.6 degrees Celsius. In the EU estimations, the square term for temperature is not significant, implying that increases in temperature will not lead to increases in the share of animal FS. This partly corresponds to global results since the average yearly temperature in the EU countries is generally lower than in many other countries around the world (like those in Africa, Latin-America, and some countries in Asia). The average yearly temperature can be seen as a proxy for climatic conditions, hence, climate change could influence the animal contribution in our overall food intake. The effect was shown to be the other way around, too, as current animal agriculture practices were estimated to have a large impact on several environmental indicators, such as GHG emission and acidification, and consequently might be contributing to climate change (Willett et al. 2020).

Limitations

One of the limitations of this study is that mean values for countries were used, though it is expected that there might be a lot of variability within a country. Because of the aggregate-level data, which are derived from quantities supplied instead of quantities consumed, there may be discrepancies between the numbers that were used in the analyses and the actual individual intakes.

Another limitation was the use of different databases collecting data for different set of countries, thus, the final sample was limited to 178 countries. In addition to that, there are some factors that we wanted to include but the data are not being collected on a global level. For some variables, we tried to use proxies (e.g. obesity), however, this might cause discrepancies in the results. Also, factors that take into account social, cultural or religious differences were harder to find in an adequate form. That is another reason why the FE method was used. It controls for all time-invariant differences between the countries, therefore, the estimated coefficients should not be biased even if we were not able to include time-invariant characteristics such as culture, religion, gender or race.

Last but not least, Stern (2004) argues that though the EKC is an empirical phenomenon, the literature is econometrically weak. He continues that there has been little attention to check the statistical properties of the data, in particular, serial dependence, stochastic trends or the possibility of omitted variable bias. In our analyses, we conducted several tests to demonstrate why the panel data approach can be used, why fixed effects is the preferred method to be employed and we checked for various assumptions. That being said, we also acknowledge that there might be limitations regarding the omitted variable bias, which is hard to be solved when conducting a global analysis with the aim of including a large set of countries.

Further research

The macroeconomic analysis focusing on evaluating the effect of income on the amount and the share of animal FS and protein in the diet was lacking in the literature. This is one of the first papers examining the association between the economic development with the consumption of animal products, specifically focusing on proteins derived from animals. Given that, it offers several opportunities for improvements. Having access to reliable databases that would collect information on several relevant factors in this area for the same set of countries would be useful. Besides conducting a global-level analysis, regional or other local analyses can be carried out, which would make the inclusion of other important factors that influence how many animal products are in the diet possible. These analyses would allow researchers to present well-fitted recommendations, which would help to better design local policies.

Further, this topic can be analysed from the micro-economic perspective to investigate consumer choices and behaviour. Looking at what influences how many animal products are consumed or how much protein people get from animal sources would be beneficial to understand where the challenges for decreasing the amount of animal products in the diet, while keeping the recommended intake of protein, lie. Similarly, willingness-to-pay analysis can be carried out to evaluate how much people are willing to pay for alternative products to meat or other plant-based substitutes. Providing information on the impacts of animal products and their plant-based alternatives, economic and other associations can be derived. This could allow us to understand what prevents people from buying these alternatives. It would help policy-makers determine factors that are important for consumers in their decision-making and consequently, how to make these products more accessible if the aim is to lower environmental and health burdens by reducing the overall animal consumption.

7 Conclusion

Dietary choices are one of the main causes of mortality and environmental degradation. Plant-based diets, in comparison to diets rich in animal products, are considered to be more sustainable because they use fewer natural resources and come with less environmental burdens. However, the rapid increase in global population and wealth has led to an increased demand for foods of animal origin. Therefore, transforming food systems to achieve sustainable and healthy diets is crucial in order to minimise the negative environmental and health impacts of our current dietary patterns (Willett et al. (2020), FAO and WHO (2019), Loken et al. (2020)). A lot of work has already been done in this area, however, the association between the economic development and the share of animal-based protein in the diet and animal food intake has not been examined more thoroughly.

Our analyses aim to shed more light into the topic of sustainable and healthy diets by looking at what factors might affect the amount or the share of animal FS and protein. The findings indicate that there is indeed a significant relationship between GDP per capita and the share of animal FS and animal protein (not significant for proteins). Our visualisations and regression results suggest that this relationship can be approximated by a quadratic function, implying that the effect of GDP per capita is not constant across all countries. On the other hand, it is dependent on the initial level of GDP per capita and follows the same pattern as the Environmental Kuznets Curve. Moreover, the resulting income elasticity that was computed is not constant either but changes according to the country's initial level of GDP per capita. It is positive for lower-income countries (with maximum of 0.29); however, it becomes negative once it reaches around \$77,000-\$81,000. One of the interpretations from the findings from the EKC model might be that countries need to get wealthy enough to afford a shift from an increasing trend in the share of animal protein.

However, the effect of GDP is not the only factor that is affecting what we consume.

Global estimations suggest that temperature might play a key role in relation to the share of animal FS in our diet. The average yearly temperature can be seen as a proxy for climatic conditions in a country, hence, climate change could influence the animal contribution in our overall food intake. That being said, prior research showed that current animal agriculture practices have a large impact on several environmental indicators, such as GHG emission and acidification, and consequently might be contributing to climate change (Willett et al. 2020) so the effect might be bidirectional.

Nevertheless, there is a need to investigate other determinants in order to use suitable instruments that would facilitate a transition towards more sustainable diets that aim to lower the amount of animal products being consumed. Findings from regional analyses and other micro-economic or behavioural studies could be able to identify factors that contribute to a decrease in consumption of animal products. Diet is only one cornerstone to the overall well-being and taking a holistic approach might be also valuable for policy-makers to better target goals concerning environmental sustainability and food security.

Acknowledgment

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References

CCKP (2021). Climate Change Knowledge Portal, World Bank Group: Data. `https://climateknowledgeportal.worldbank.org/download-data`. Online. Accessed 2021-11-14.

Chiu, Y.-B. (2012). Deforestation and the Environmental Kuznets Curve in Developing Countries: A Panel Smooth Transition Regression Approach. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 60(2):177–194.

Collischon, M. and Eberl, A. (2020). Let's Talk About Fixed Effects: Let's Talk About All the Good Things and the Bad Things. *KZfSS Kolner Zeitschrift fur Soziologie und Sozialpsychologie*, 72:289–299.

Dietz, S. and Adger, W. N. (2003). Economic growth, biodiversity loss and conservation effort. *Journal of Environmental Management*, 68(1):23–35.

FAO (2020). World Food and Agriculture - Statistical Yearbook 2020. Technical report, FAO, Rome, Italy.

FAO (2021). FAOSTAT Datasets. `http://www.fao.org/faostat/en/#data`. Online. Accessed 2021-04-05.

FAO and WHO (2019). Sustainable healthy diets - Guiding principles. Technical report, FAO and WHO, Rome, Italy.

Fransen, E. (2011). Identifying the driving forces of global beef consumption: A Panel Data Analysis. Master's thesis, Wageningen University, Department of Social Sciences. unpublished thesis.

Gerten, D., Heck, V., Jagermeyr, J., Bodirsky, B. L., Fetzer, I., Jalava, M., Kummu, M., Lucht, W., Rockstrom, J., Schaphoff, S., and Schellnhuber, H. J. (2020). Feeding ten billion people is possible within four terrestrial planetary boundaries. *Nat. Sustain.*, 3(3):200–208.

Gossard, M. and York, R. (2003). Social Structural Influences on Meat Consumption. *Human Ecology Review*, 10.

Gray, A. (2016). Which countries spend the most on food? `https://www.weforum.org/agenda/2016/12/this-map-shows-how-much-each-country-spends-on-food/`. World Economic Forum. Online. Accessed 2021-03-31.

Grossman, G. and Krueger, A. (1992). Environmental impacts of a north american free trade agreement. *Social Science Electronic Publishing*, 8.

Henchion, M., Hayes, M., Mullen, A., Fenelon, M., and Brijesh Kumar, T. (2017). Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods*, 6:53.

Hlavac, M. (2018). *stargazer: Well-Formatted Regression and Summary Statistics Tables.* Central European Labour Studies Institute (CELSI), Bratislava, Slovakia. R package version 5.2.2.

Hoffmann, J. P. (2004). Social and Environmental Influences on Endangered Species: A Cross-National Study. *Sociological Perspectives*, 47(1):79–107.

Investopedia (2021). What is purchasing power parity (ppp)? `https://www.investopedia.com/updates/purchasing-power-parity-ppp/`. Online. Accessed 2021-05-11.

IPCC (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Summary for Policymakers. Technical report, IPCC.

Kovljenic, M. and Savic, M. (2017). Factors influencing meat and fish consumption in Serbian households: Evidence from SILC database. *Ekonomika poljoprivrede*, 64:945–956.

Kuznets, S. (1984). *Economic Growth and Income Inequality*, pages 25–37.

Lee, A., Mhurchu, C., Sacks, G., Swinburn, B., Snowdon, W., Vandevijvere, S., Hawkes, C., L'abbe, M., Rayner, M., Sanders, D., Barquera, S., Friel, S., Kelly, B., Kumanyika, S., Lobstein, T., Ma, J., Macmullan, J., Mohan, S., Monteiro, C., and Neal, B. (2013). Monitoring the price and affordability of foods and diets globally. *Obesity reviews: an official journal of the International Association for the Study of Obesity*, 14:82–95.

Loken, B., Opperman, J., Orr, S., Fleckenstein, M., Halevy, S., McFeely, P., Sarah Park, S., and Weber, C. (2020). Bending the Curve: The Restorative Power of Planet-Based Diets. Technical report, WWF, Gland, Switzerland.

Maslow, A. (1943). A theory of human motivation. *Psychological review*, 50:370.

McLeod, S. A. (2020). Maslow's hierarchy of needs. simply psychology. `https://www.simplypsychology.org/maslow.html`. Online. Accessed 2021-05-19.

Mcneill, D., Verburg, R., and Bursztyn, M. (2011). Institutional context for sustainable development. *Journal of Nanoparticle Research - J NANOPART RES.*

Mills, J. H. and Waite, T. A. (2009). Economic prosperity, biodiversity conservation, and the environmental Kuznets curve. *Ecological Economics*, 68(7):2087–2095.

Muhammad, A., D'Souza, A., Meade, B., Micha, R., and Mozaffarian, D. (2017). How income and food prices influence global dietary intakes by age and sex: Evidence from 164 countries. *BMJ Global Health*, 2:e000184.

NCD-RisC (2021). NCD Risk Factor Collaboration, WHO Collaborating Centre on NCD Surveillance and Epidemiology: Data. `https://www.ncdrisc.org/data-downloads-adiposity.html`. Online. Accessed 2021-11-10.

OECD (2021). OECD data. `https://data.oecd.org/`. Online. Accessed 2021-04-05.

Otten, J., Hellwig, J., and Meyers, L. (2006). *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements.*

Paivarinta, E., Itkonen, S., Pellinen, T., Lehtovirta, M., Erkkola, M., and Pajari, A.-M. (2020). replacing animal-based proteins with plant-based proteins changes the composition of a whole nordic diet - a randomised clinical trial in healthy finnish adults. page 943.

Panayotou, T. (1997). Demystifying the environmental kuznets curve: turning a black box into a policy tool. *Environment and Development Economics*, 2(4):465–484.

Perisse, J., Sizaret, F., and Francois, P. (1969). The effect of income on the structure of the diet. *F.A.O. Nutrition Newsletter*, 7(3):1–9.

Selden, T. M. and Song, D. (1994). Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions? *Journal of Environmental Economics and Management*, 27(2):147–162.

Shafik, N. (1994). Economic Development and Environmental Quality: An Econometric Analysis. *Oxford Economic Papers*, 46(0):757–773.

Song, M., Fung, T. T., Hu, F. B., Willett, W. C., Longo, V. D., Chan, A. T., and Giovannucci, E. L. (2016). Association of Animal and Plant Protein Intake With All-Cause and Cause-Specific Mortality. *JAMA Internal Medicine*, 176(10):1453–1463.

Stern, D. I. (2004). The rise and fall of the environmental kuznets curve. *World Development*, 32(8):1419–1439.

UN (2021). UN data. `http://data.un.org/Default.aspx`. Online. Accessed 2021-04-14.

Valin, H., Sands, R., Van der Mensbrugghe, D., Nelson, G., Ahammad, H., Blanc, E., Bodirsky, B., Fujimori, S., Hasegawa, T., Havlik, P., Heyhoe, E., Kyle, P., Mason-D'Croz, D., Paltsev, S., Rolinski, S., Tabeau, A., Meijl, H., von Lampe, M., and Willenbockel, D. (2014). The Future of Food Demand: Understanding Differences in Global Economic Models. *Agricultural Economics*, 45.

WHO (2020). Healthy diet. `https://www.who.int/news-room/fact-sheets/detail/healthy-diet`. Online. Accessed 2021-03-27.

Willett, W., Rockstrom, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S. E., Srinath Reddy, K., Narain, S., Nishtar, S., and Murray, C. J. L. (2020). Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Technical Report 10170, The Lancet.

Wooldridge, J. M. (2013). *Introductory Econometrics: A Modern Approach*, volume 5. Cengage Learning.

WRAP (2019). Food Futures: From Business as Usual to Business Unusual. Technical report, WRAP. vailable online: http://www.wrap. org.uk/content/food-futures (accessed on 4 May 2021).

A Supplementary figures

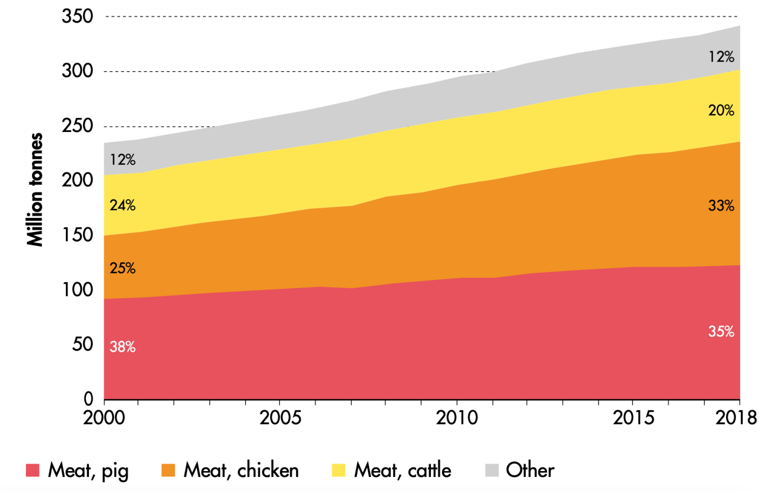

Figure A.1: World production of meat, main items, Source: FAO (2020).

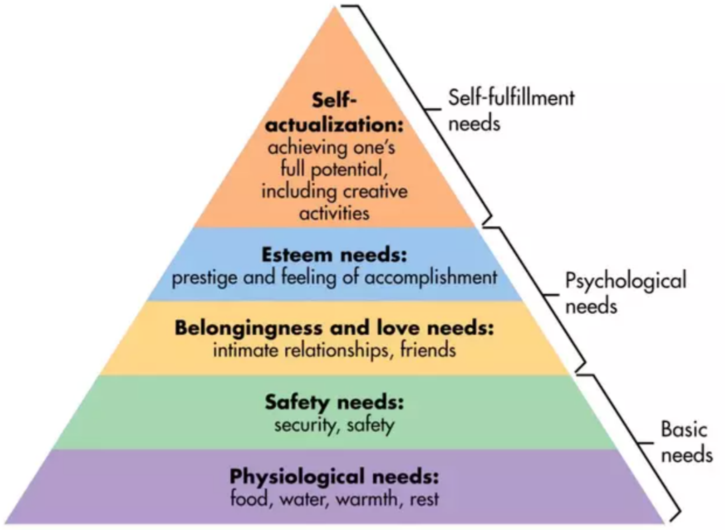

Figure A.2: Maslow's Hierarchy of Needs, Source: McLeod (2020).

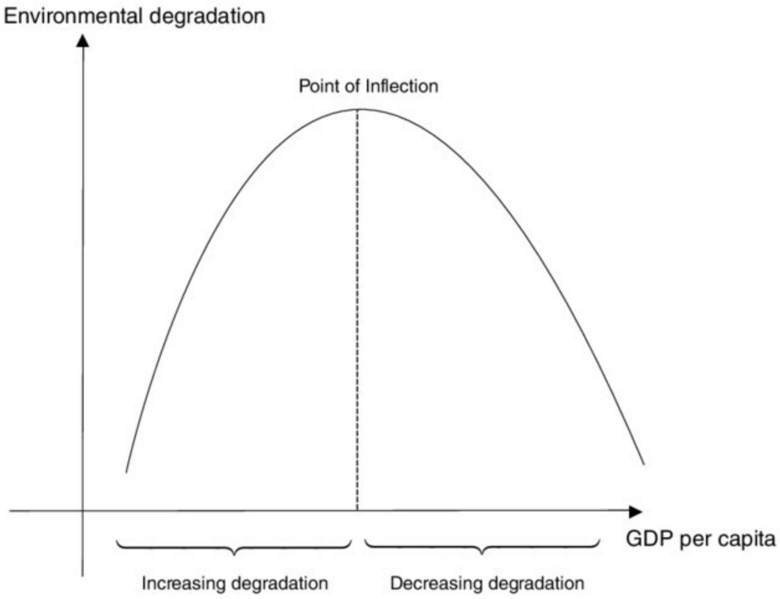

Figure A.3: Environmental Kuznets Curve – the relationship between GDP per capita and the level of environmental degradation, Source: Mcneill et al. (2011).

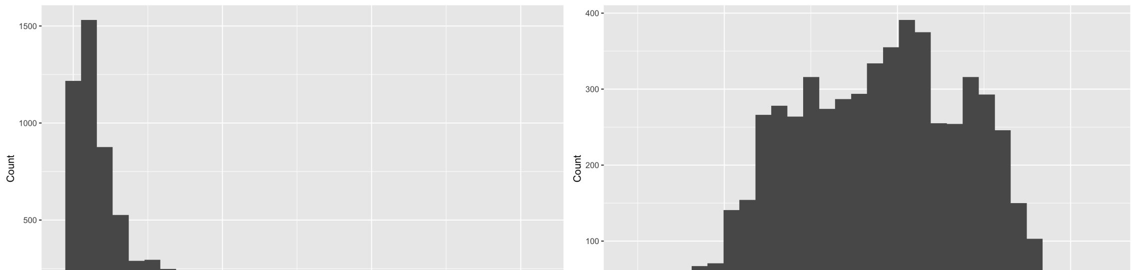

Figure A.4: Histogram of GDP, showing the distribution of GDP per capita expressed as a frequency (left) and the distribution of the logarithm of GDP per capita expressed as a frequency (right).

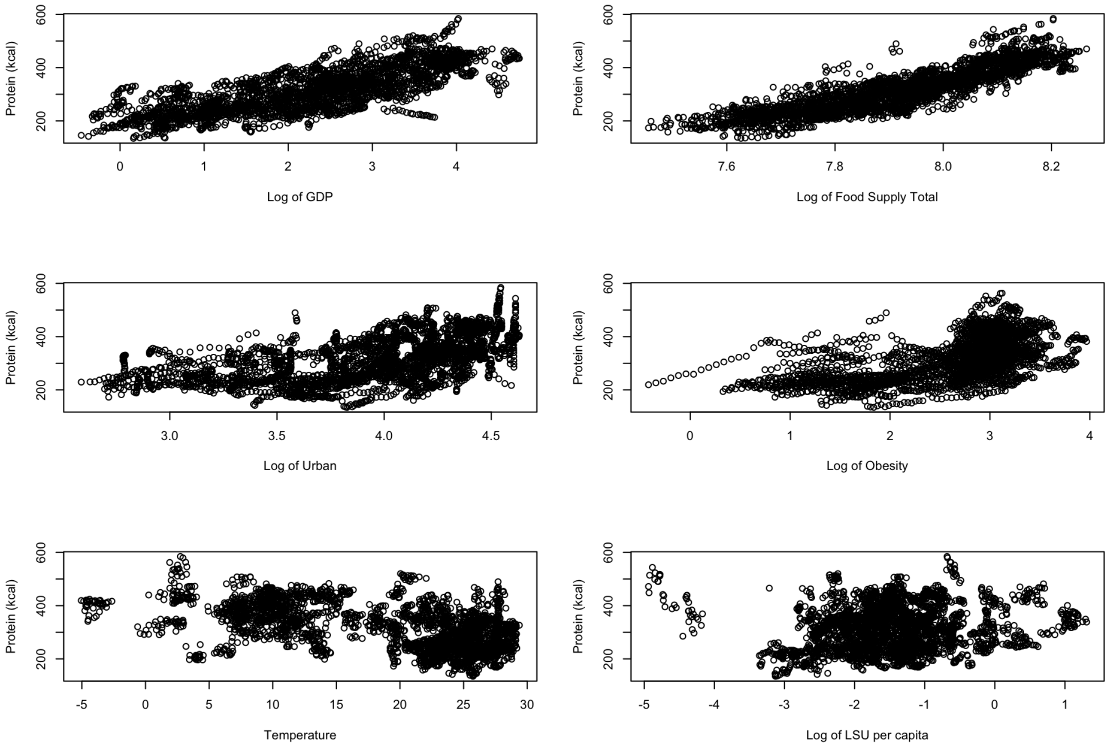

Figure A.5: Plots showing the association between selected independent variables and the amount of protein (in kcal).

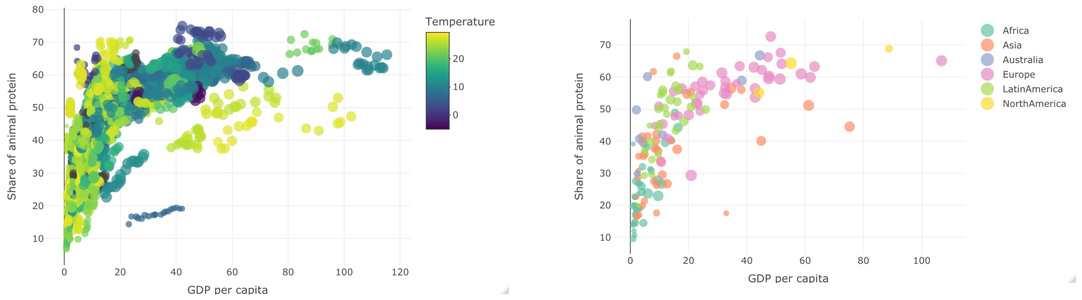

Figure A.6: The relationship between GDP per capita and the share of animal protein conditional on temperature (left) and continents (right).

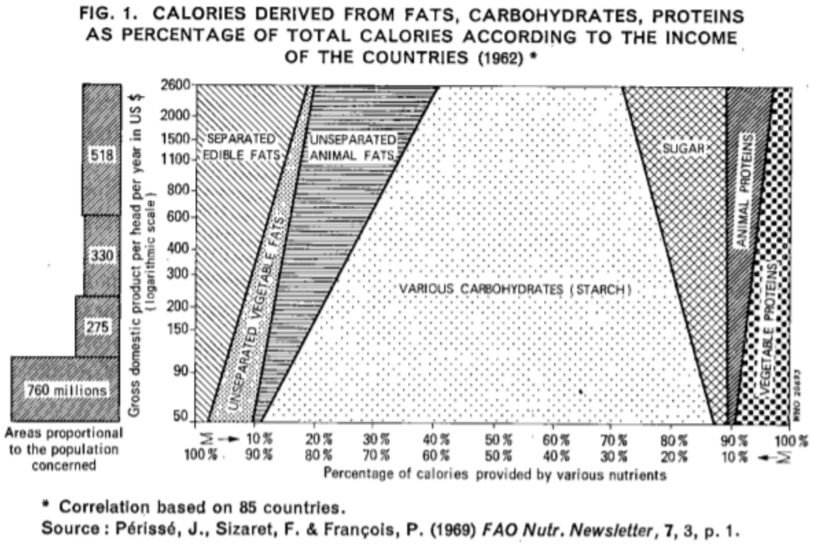

Figure A.7: Macronutrient composition vs. GDP, 1962 (85 countries), Source: Perisse et al. (1969).

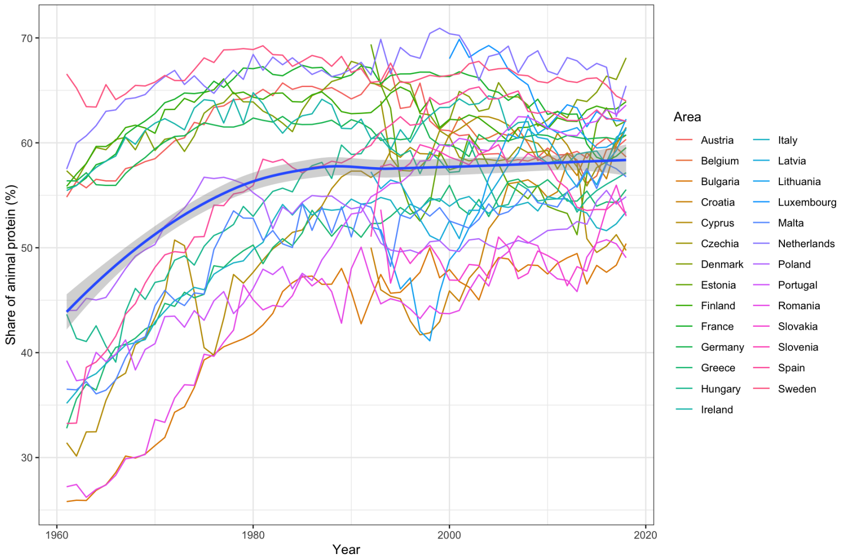

Figure A.8: The evolution of the share of animal-based protein out of the total dietary protein in the European Union from 1961 to 2018. The mean value is represented by the dark blue line and the confidence intervals are filled by light grey.

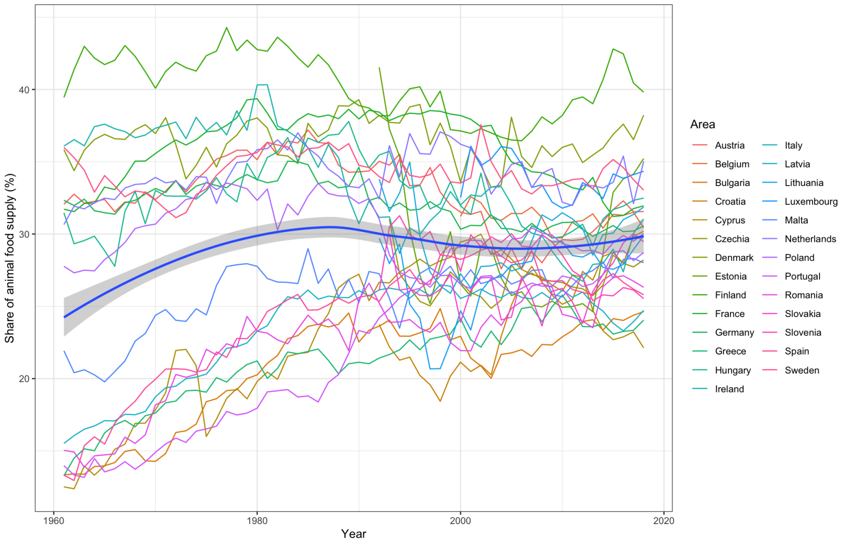

Figure A.9: The evolution of the share of animal food supply in the European Union from 1961 to 2018. The mean value is represented by the dark blue line and the confidence intervals are filled by light grey.

B Supplementary tables

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
log(GDP)	6.86	8.57	9.55	9.41	10.32	11.67
GDP	955	5,248	13,984	20,613	30,427	116,786

Table B.1: Summary statistics for log(GDP) and GDP for better interpretation of Figure 7. Based on data from UN (2021) (dataset contained information on GDP per capita for 178 countries in 2018).

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
P.A.Share	1.121	3.020	4.880	4.988	6.648	11.498
P.V.Share	4.156	5.094	6.104	6.310	7.404	11.040

Table B.2: Summary statistics for the share of animal (P.A.Share) and vegetal (P.V.Share) protein expressed in percentages (out of the total food supply) based on data from FAO (2021) (dataset contained information for 178 countries in 2018).

Table B.4: Variation inflation factor for 6 different models.

	log FS.A.kcal	log FS.A.Share	Protein.kcal	Protein.Share	log P.A.kcal	log P.A.Share
log(GDP)	4.075	3.146	4.075	3.838	3.753	3.146
log(FS)	3.003	1.792	3.003	2.901	2.180	1.792
log(Urban)	2.901	1.553	2.901	2.915	1.921	1.553
log(Obese)	4.758		4.758	4.791	2.676	
log(Under)	6.092		6.092	6.114	3.636	
Temp	1.688	2.083	1.688	1.666	2.193	2.083
log(LSU.cap)	1.052	1.227	1.052		1.295	1.227
Edu.TRY		2.580			2.996	2.580
Edu.BUSRY		2.927			2.886	2.927

	Africa	Asia	Australia	Europe	LatinAmerica	NorthAmerica	Global
FS	2457.80	2718.30	2889.82	3261.25	2691.85	3341.29	2791.14
FS.A.kcal	219.39	468.53	651.37	927.03	552.01	917.63	543.62
FS.A.Share	8.80	16.66	22.07	28.29	20.33	27.70	18.50
P.kcal	63.44	78.11	80.97	99.66	74.66	101.94	79.21
P.Share	10.27	11.40	11.13	12.20	11.07	12.26	11.23
P.A.kcal	66.55	128.88	177.29	224.54	149.35	252.56	143.46
P.A.Share	25.55	38.62	52.60	55.67	48.85	62.19	42.28

Table B.3: Mean values of certain variables (expressed in kcal or %) from our dataset from 2000 to 2018 for continents and globally.

C Countries used in the analysis

Global (and regional) analyses were based on the sample of the following countries from the respective continents:

Africa (46 countries):

- Algeria, Angola, Benin, South Africa, Zambia, Morocco, Madagascar, Botswana, Burkina Faso, Cabo Verde, Cameroon, Central African Republic, Chad, Congo, Cote d'Ivoire, Djibouti, Egypt, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea–Bissau, Kenya, Lesotho, Liberia, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Sudan, Sudan (former), Togo, Tunisia, Uganda, United Republic of Tanzania, Zimbabwe

Asia (42 countries):

- Armenia, Azerbaijan, Bangladesh, Japan, Democratic People's Republic of Korea, China, India, Indonesia, Kazakhstan, Israel, Saudi Arabia, Hong Kong SAR, China, Singapore, Afghanistan, Brunei Darussalam, Cambodia, Georgia, Iran (Islamic Republic of), Iraq, Kuwait, Kyrgyzstan, Lao People's Democratic Republic, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Republic of Korea, Sri Lanka, Tajikistan, Thailand, Timor-Leste, Turkmenistan, United Arab Emirates, Uzbekistan, Viet Nam, Yemen, Jordan

Australia (9 countries):

- Australia, New Zealand, Fiji, French Polynesia, Kiribati, New Caledonia, Samoa, Solomon Islands, Vanuatu

Europe (42 countries):

- Albania, Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom of Great Britain and Northern Ireland, Estonia, Russian Federation, Slovenia, Latvia, Lithuania, Bulgaria, Croatia, Cyprus, Malta, Romania, North Macedonia, Belarus, Bosnia and Herzegovina, Montenegro, Republic of Moldova, Serbia, Serbia and Montenegro, Ukraine

Latin America (34 countries):

- Antigua and Barbuda, Bahamas, Barbados, Mexico, Chile, Colombia, Brazil, Argentina, Costa Rica, Peru, Belize, Bolivia (Plurinational State of), Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Netherlands Antilles (former), Nicaragua, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela (Bolivarian Republic of)

North America (3 countries):

- Canada, United States of America, Bermuda

The European Union sample consists of following 27 countries:

- Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden

D Supplementary analyses

D.1 Log Model for Animal Food Supply

Here, we look into what influences the amount and the share of animal food supply. The logarithm of the dependent variable ($y_{it} = \log(FS.A.kcal_{it})$ or $y_{it} = \log(FS.A.Share_{it})$) is taken and the vector of explanatory variables from the Equation 1 has the following form for the amount of animal food supply in kcal:

$$\begin{aligned} X_{it} = (\,&\log(GDP_{it}), \log(FS_{it}), \log(Urban_{it}), \log(Obese_{it}), \\ &\log(Underweight_{it}), Temperature_{it}, \log(LSU.capita_{it})), \end{aligned}$$

and for the share of animal food supply:

$$\begin{aligned} X_{it} = (\,&\log(GDP_{it}), \log(FS_{it}), \log(Urban_{it}), Temperature_{it}, \\ &\log(LSU.capita_{it}), Edu.TRY_{it}, Edu.BUSRY_{it}). \end{aligned}$$

The variables of interest take the functional form of logarithm to allow us examine the elasticities between them. In Figure D.10 and Figure D.11, the associations that can be expected are displayed. The hypothesis is that as income grows, the amount of animal food supply increases, as well. Analogically, the relationship between the total food supply, urban population or obesity and the dependent variable seems to be positive. On the other hand, temperature and the percentage of underweight people seem to be negatively associated.

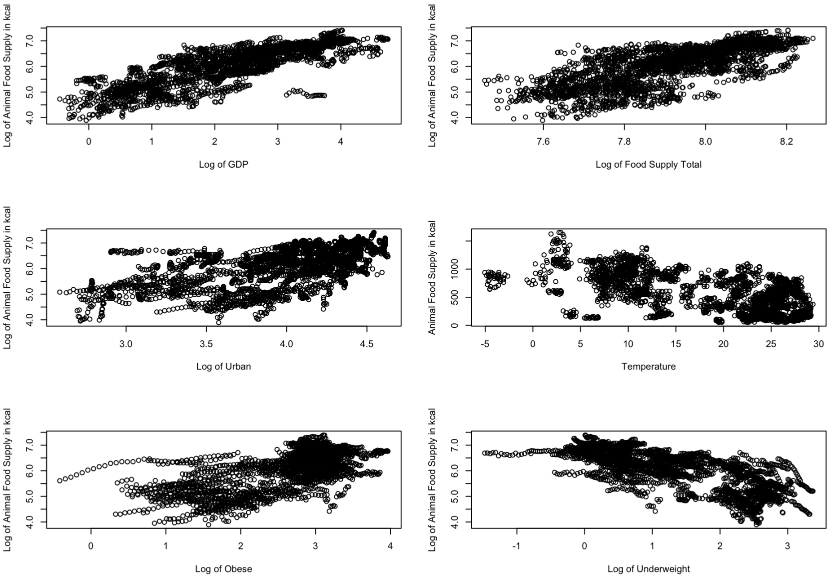

Figure D.10: Plots showing the association between selected independent variables and the amount of animal food supply.

Table D.5 shows the results for the animal food supply in absolute and relative terms. Globally, it is suggested that GDP is indeed significant and positively associated with the

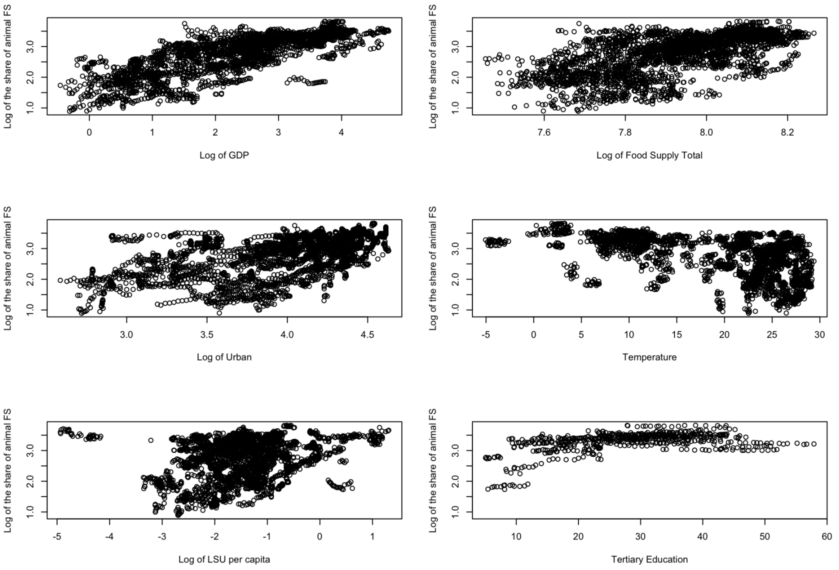

Figure D.11: Plots showing the association between selected independent variables and the share of animal food supply.

amount as well as the share of animal food supply. On average, every increase of GDP by 10% is estimated to increase the amount of animal food supply by 1.7% and the share of animal food supply by approximately 2.5 – 2.7% while holding other variables fixed. For the EU countries, the impact of GDP is also very significant, but compared to the global estimation, the effect on the amount of animal food supply is estimated to be larger (2.2%) and the effect on the share of animal FS seems to be smaller (1.6 – 1.7%).

In case of the amount of animal food supply, Global and EU estimates follow the same trends. The variables that result to be significant are GDP per capita (GDP), total food supply (FS) and livestock units per capita (LSU.cap). Country FE and country and time FE estimates seem to always suggest a similar effect of the variables. Increasing total food supply by 10% leads to an increase in the amount of animal FS by 9.7-9.8%. However, FS does not seem to have a significant effect on the share of animal food supply, meaning that increasing the amount of food we eat does not really influence whether the share of animal FS is higher or lower. Regarding livestock units per capita, it seems to have a large effect on both the amount and the share of animal FS, which is shown by the results in global as well as EU sample. If LSU.cap rises by 10%, the amount of animal FS increases on average by around 2.3% (Global) and 2.1% (EU) holding other variables fixed. Globally, the share of animal FS was estimated to increase by 1.5%, however, the increase in the share of animal FS in the EU is estimated to be a bit higher, of around 2.3 – 2.6%, increasing LSU.cap by 10%.

In case of temperature, the results are different. In the global and EU estimation (country FE) of the amount of animal FS, temperature was found to be significant, though only on 10% level, while the country and time FE estimation suggests that this variable is insignificant. In case of the share of animal FS, temperature is significant using country FE only for the whole dataset (global estimation), otherwise (using country and time FE or overall for the EU sample) it was found to be insignificant. In the estimation of the share of animal FS, education results to be significant when using country and time FE[17]. Globally, if the share of people with tertiary education rises by one percentage point, the share of animal FS decreases on average by 0.5%. The effect of education is not that significant in the EU sample. Using country and time FE estimation, if the share of people with the highest level of education corresponding to bellow upper-secondary rises by one percentage point, in other words, there is a higher prevalence of lower educated people, the share of animal FS might increase by around 0.3%, but it is significant only on 10% level. The remaining variables did not result to be significant.

Adjusted R^2 from the global regressions ranges from 0.22 to 0.43, which means that approximately 22% of the variation in the share of animal FS can be explained by the variation in the explanatory variables and around 30-40% of the variation in the amount of animal FS can be explained by the variation in the corresponding explanatory variables. This implies that there are other factors that cause changes in our dependent variable. In case of the EU regressions, adjusted R^2 ranges from 0.14 to 0.37.

D.2 Log Model for Animal Proteins

Now, the factors influencing the amount and the share of animal proteins are examined. The logarithm of the dependent variable ($y_{it} = \log(P.A.kcal_{it})$ or $y_{it} = \log(P.A.Share_{it})$) is taken and the vector of explanatory variables from the Equation 1 has the following form for the amount of animal protein in kcal:

$$\begin{aligned} X_{it} = (\,&\log(GDP_{it}), \log(FS_{it}), \log(Urban_{it}), \log(Obese_{it}),\\ &\log(Underweight_{it}), Temperature_{it}, \log(LSU.capita_{it}),\\ &Edu.TRY_{it}, Edu.BUSRY_{it}), \end{aligned}$$

and for the share of animal protein:

$$\begin{aligned} X_{it} = (\,&\log(GDP_{it}), \log(FS_{it}), \log(Urban_{it}), Temperature_{it},\\ &\log(LSU.capita_{it}), Edu.TRY_{it}, Edu.BUSRY_{it}). \end{aligned}$$

After examining possible associations between the variables (Figure D.12), the functional form of the variables was set, which helped us determine elasticities between the variables. Again, the main hypothesis is that the amount of animal protein increases as income grows, since people have resources to diversify their diet, meaning that they can both get more protein as well as afford to buy animal products. Analogically, the relationship between the total food supply or urban population and the dependent variable seems to be positive. The relationship between the livestock per capita is not as clear but suggests a positive relationship, too. On the other hand, the prevalence of underweight people seems to be negatively associated with the amount of animal protein. The relationship with education variables is not very clear.

Table D.6 displays the regressions results for the animal protein in absolute and relative values. In all cases, GDP per capita and livestock units per capita result to be very significant and exhibit a positive association in relation to the dependent variables. On average, every increase of GDP by 10% is estimated to increase the amount of animal protein by approximately 2.1% and the share of animal protein by approximately 2.3% while holding other variables fixed. For the EU sample, the impact of GDP is slightly

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[17] It does not result to be significant using country FE.

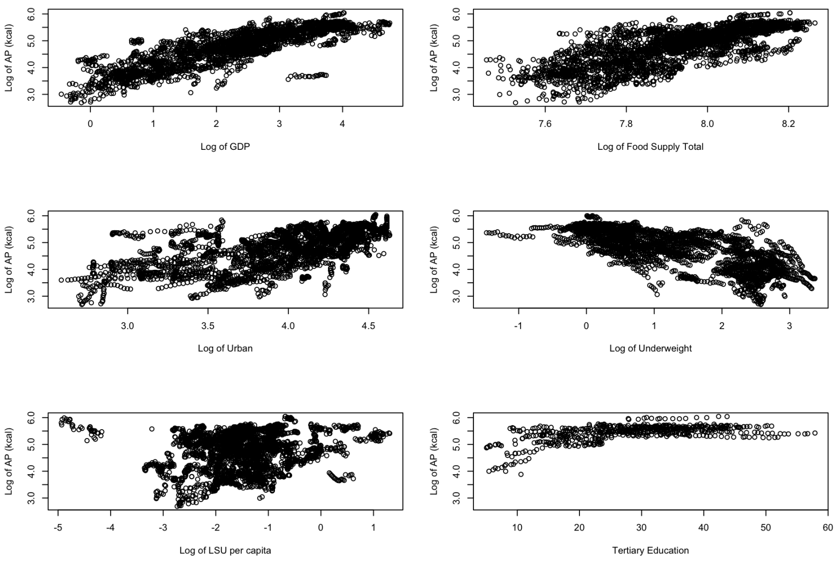

Figure D.12: Plots showing the association between selected independent variables and the amount of animal protein (in kcal).

smaller, leading to a 2% increase in the amount of animal protein and 1.7% increase in the its share for every 10% increase in GDP per capita. Regarding livestock units per capita, every 10% rise is associated with almost 3% increase in the amount and 1% increase in the share of animal protein. For the EU countries, it is around 4.6% and 1.7% respectively. The reasoning might be that when there are more animal farms in the EU countries, their citizens are more likely to afford meat (compared to other developed countries, where even larger animal farms might not have the same positive effect on the amount of animal protein since they might export the meat abroad), hence, the animal intake would rise.

Total food supply is also positively related to the amount of animal protein, however, it is insignificant in relation to the share of animal protein out of the total protein. These results are in line with the findings regarding the amount and the share of animal FS, suggesting again that food supply has mainly effect on the animal intake in absolute terms, not in relative. What influences the amount of animal protein globally is the prevalence of undernutrition. Higher the prevalence, the lower the amount of animal protein. This variable is not significant using the EU dataset, though.

With respect to the share of animal protein, education seems to play a role. If the share of people with tertiary education rises by ten percentage points, the share of animal protein decreases on average by around $4-6\%$ globally, and particularly in the EU by $3-5\%$ holding other variables fixed. Moreover, the percentage of urban population might be influential on the share of animal protein on a global scale (it is insignificant for the EU sample). The results suggest that a 10% increase in the percentage of urban population is associated with a 3% increase in the share of animal protein. This can be due to higher wages in cities, which can lead to people being able to afford meat more.

D.3 Derivation of income elasticity

The simple version of the EKC model was used to derive the income elasticity for the share of animal FS and protein. The formula to calculate the income elasticity[18] is as follows:

$$\begin{aligned}\epsilon =& \frac{\frac{\delta FS.A.Share}{FS.A.Share}}{\frac{\delta GDP}{GDP}} = \frac{\delta FS.A.Share}{\delta GDP}\frac{GDP}{FS.A.Share} = \\ &= (\beta_1 + 2\beta_2 GDP)\frac{GDP}{FS.A.Share} = \\ &= \frac{GDP(\beta_1 + 2\beta_2 GDP)}{\beta_0 + \beta_1 GDP + \beta_2 GDP^2}\end{aligned} \tag{3}$$

The estimated elasticity is therefore:

$$\hat{\epsilon} = \frac{\hat{\beta_1} GDP + 2\hat{\beta_2} GDP^2}{\hat{\beta_0} + \hat{\beta_1} GDP + \hat{\beta_2} GDP^2} \tag{4}$$

D.4 Robustness checks

For robustness check, countries were divided into quartiles according their income (Q1-Q4). In addition to that, two more groups (GDP>\$50,000 and GDP>\$80,000) were created to estimate the elasticity for the group of countries that might be located after the estimated turning point. Models for the share of animal food supply and protein in logarithmic form with $X_{it} = (\log(GDP_{it}), \log(FS_{it}), \log(Urban_{it}), Temperature_{it}, \log(LSU.capita_{it})$ are employed to derive elasticities for these specific groups of countries, which will allow us to compare the results with the estimated elasticities from the EKC model.

Countries in the first quartile (Q1) do not show a strong relationship between GDP and the share of animal FS or protein (Table D.7 and Table D.8). In contrast, the dependent variables are affected mainly by livestock units per capita (positively). This positive association is present for almost all income groups[19].

The remaining quartile groups show a significant association between GDP and the share of animal FS or protein[20]. Income elasticity is positive, however, it is not constant across different income groups. The maximum (0.21-0.23) is reached in Q2 group, then the elasticity decreases, which is consistent with the findings from the EKC analysis. There were less countries in groups GDP50 and GDP80, but GDP still resulted to be significant for GDP50. In case of GDP80, we had only 27 observations but the income elasticity for animal protein was estimated to be negative (though insignificant).

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[18] The elasticity for the share of animal FS is shown. Analogically, we derived the elasticity for the share of animal protein.

[19] Livestock units per capita is not significant for the third quartile (for both the share of animal FS and protein) and GDP80 (for the share of animal FS).

[20] Not that strong for Q3 for the share animal FS.

Table D.5: Regression results for the Global and the EU Log Model for the amount and the share of animal food supply. FE estimation using robust SE is presented. Both unit (country) effects and unit and time effects were employed.

	Global				*EU*			
	log(FS.A.kcal)		log(FS.A.Share)		log(FS.A.kcal)		log(FS.A.Share)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(GDP)	0.173***	0.170***	0.248***	0.270***	0.215***	0.223***	0.170***	0.153**
	(0.051)	(0.053)	(0.074)	(0.104)	(0.048)	(0.067)	(0.063)	(0.069)
log(FS)	0.971***	0.987***	−0.138	−0.279	0.981**	0.974**	−0.211	−0.320
	(0.207)	(0.201)	(0.274)	(0.296)	(0.392)	(0.411)	(0.465)	(0.457)
log(Urban)	0.125	0.155	0.322*	0.201	0.198	0.373	0.014	−0.105
	(0.155)	(0.170)	(0.176)	(0.191)	(0.289)	(0.319)	(0.266)	(0.278)
log(Obese)	0.053	0.010			0.115	−0.116		
	(0.085)	(0.107)			(0.312)	(0.386)		
log(Under)	0.051	0.113			0.219	0.273		
	(0.087)	(0.111)			(0.277)	(0.263)		
Temperature	0.007*	0.005	0.010**	0.003	0.010*	0.010	0.007	0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.007)	(0.005)	(0.008)
log(LSU.cap)	0.228***	0.236***	0.155***	0.152***	0.203***	0.207***	0.225***	0.256***
	(0.053)	(0.055)	(0.056)	(0.053)	(0.068)	(0.068)	(0.055)	(0.055)
Edu.BUSRY			0.001	0.001			0.003	0.003*
			(0.001)	(0.001)			(0.002)	(0.002)
Edu.TRY			−0.002	−0.005***			0.001	−0.003
			(0.002)	(0.002)			(0.002)	(0.002)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2,545	2,545	589	589	459	459	364	364
R^2	0.467	0.341	0.288	0.302	0.415	0.413	0.208	0.243
Adjusted R^2	0.432	0.293	0.228	0.218	0.370	0.342	0.147	0.138

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table D.6: Regression results for the Global and the EU Log Model for the amount and the share of animal proteins in the diet. FE estimation using robust SE is presented. Both unit (country) effects and unit and time effects were employed.

	Global				*EU*			
	log(P.A.kcal)		log(P.A.Share)		log(P.A.kcal)		log(P.A.Share)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(GDP)	0.217***	0.269***	0.226***	0.253***	0.208***	0.204***	0.173***	0.168***
	(0.056)	(0.064)	(0.059)	(0.081)	(0.053)	(0.072)	(0.033)	(0.043)
log(FS)	1.029***	0.917***	−0.066	−0.146	0.711**	0.690**	−0.221	−0.286
	(0.223)	(0.234)	(0.164)	(0.184)	(0.321)	(0.304)	(0.204)	(0.201)
log(Urban)	0.001	−0.111	0.329**	0.292*	−0.157	−0.122	0.032	−0.021
	(0.282)	(0.371)	(0.152)	(0.164)	(0.280)	(0.335)	(0.173)	(0.173)
log(Obese)	−0.108	−0.041			0.351	0.312		
	(0.160)	(0.176)			(0.300)	(0.330)		
log(Under)	−0.366***	−0.428**			0.126	0.158		
	(0.137)	(0.180)			(0.251)	(0.255)		
Temperature	0.002	0.001	0.004*	0.001	−0.002	0.007	0.002	−0.001
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.005)	(0.002)	(0.004)
log(LSU.cap)	0.299***	0.268***	0.121***	0.110**	0.452***	0.461***	0.163***	0.185***
	(0.071)	(0.069)	(0.039)	(0.045)	(0.092)	(0.109)	(0.043)	(0.054)
Edu.TRY	−0.004*	−0.004	−0.004***	−0.006***	−0.003	−0.003	−0.003*	−0.005***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)	(0.002)	(0.001)
Edu.BUSRY	0.001	0.001	−0.001	−0.002	0.001	0.001	−0.001	−0.0004
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	519	519	589	589	324	324	364	364
R^2	0.603	0.592	0.431	0.438	0.527	0.521	0.331	0.345
Adjusted R^2	0.564	0.535	0.384	0.371	0.482	0.446	0.280	0.255

Note: *p<0.1; **p<0.05; ***p<0.01

Table D.7: Regression results for different income groups (divided in quartiles) for the Log Model for the share of animal FS in the diet. FE estimation using robust SE is presented.

	Dependent variable: Log(FS.A.Share)					
	(Q1)	(Q2)	(Q3)	(Q4)	(GDP50)	(GDP80)
log(GDP)	0.194	0.210***	0.120*	0.177***	0.184**	0.239
	(0.142)	(0.080)	(0.068)	(0.055)	(0.088)	(0.142)
log(FS)	−0.790*	0.296**	0.296	0.064	−0.008	2.129*
	(0.464)	(0.148)	(0.366)	(0.252)	(0.509)	(1.186)
log(Urban)	0.383	−0.326	0.173*	−0.062	−0.416	−1.093
	(0.258)	(0.248)	(0.098)	(0.205)	(0.561)	(0.932)
Temp	0.024	0.022*	−0.0002	0.007	0.013*	0.014
	(0.030)	(0.012)	(0.009)	(0.005)	(0.006)	(0.010)
log(LSU.cap)	0.572***	0.141**	−0.015	0.223***	0.198**	0.066
	(0.118)	(0.067)	(0.037)	(0.052)	(0.081)	(0.170)
Observations	735	699	700	734	190	27
R^2	0.352	0.225	0.145	0.168	0.264	0.323
Adjusted R^2	0.300	0.147	0.058	0.105	0.186	0.073
Note:						*p<0.1; **p<0.05; ***p<0.01

Table D.8: Regression results for different income groups (divided in quartiles) for the Log Model for the share of animal proteins in the diet. FE estimation using robust SE is presented.

	Dependent variable: Log(P.A.Share)					
	(Q1)	(Q2)	(Q3)	(Q4)	(GDP50)	(GDP80)
log(GDP)	0.216^{*}	0.226^{***}	0.138^{***}	0.167^{***}	0.105^{**}	-0.012
	(0.120)	(0.063)	(0.047)	(0.035)	(0.047)	(0.196)
log(FS)	-0.712^{*}	0.252^{*}	0.160	-0.161	0.076	2.032^{**}
	(0.386)	(0.132)	(0.236)	(0.212)	(0.293)	(0.864)
log(Urban)	0.308	-0.253	0.149^{**}	-0.109	-0.498	-1.237^{*}
	(0.210)	(0.172)	(0.059)	(0.149)	(0.348)	(0.625)
Temp	0.018	0.021^{**}	-0.0003	-0.001	0.007^{**}	0.015
	(0.027)	(0.010)	(0.007)	(0.003)	(0.004)	(0.009)
log(LSU.cap)	0.392^{***}	0.124^{**}	0.034	0.145^{***}	0.186^{***}	0.169^{***}
	(0.099)	(0.059)	(0.025)	(0.041)	(0.055)	(0.059)
Observations	735	699	700	734	190	27
R^2	0.294	0.316	0.216	0.223	0.412	0.663
Adjusted R^2	0.237	0.247	0.136	0.163	0.350	0.538
Note:						*p<0.1; **p<0.05; ***p<0.01

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