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Drivers of meat consumption

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ABSTRACT

Increasing global levels of meat consumption are a threat to the environment and to human health. To identify measures that may change consumption patterns towards more plant-based foods, it is necessary to improve our understanding of the causes behind the demand for meat. In this paper we use data from 137 different countries to identify and assess factors that influence meat consumption at the national level using a cross-country multivariate regression analysis. We specify either total meat or ruminant meat as the dependent variable and we consider a broad range of potential drivers of meat consumption. The combination of explanatory variables we use is new for this type of analysis. In addition, we estimate the relative importance of the different drivers. We find that income per capita followed by rate of urbanisation are the two most important drivers of total meat consumption per capita. Income per capita and natural endowment factors are major drivers of ruminant meat consumption per capita. Other drivers are Western culture, Muslim religion, female labour participation, economic and social globalisation and meat prices. The main identified drivers of meat demand are difficult to influence through direct policy intervention. Thus, acting indirectly on consumers' preferences and consumption habits (for instance through information, education policy and increased availability of ready-made plant based products) could be of key importance for mitigating the rise of meat consumption per capita all over the world.

1. Introduction

Between 1961 and 2011 the world population rose from 3 to almost 7 billion (by 128%), while the global average meat consumption per capita increased by 75%, so that global meat consumption and production almost quadrupled (FAO, 2016). This has consequences for the environment, human health and global food security (Tilman & Clark, 2014).

More than half of the proteins in harvested crops on global croplands are fed to animals (Bodirsky et al., 2015), and grazing areas to feed ruminants cover approximately one quarter of global land area (Stehfest et al., 2009). Animal production is therefore also a major driver of man-made global environmental disturbance, causing both deforestation, nutrient pollution and land degradation, in addition to global greenhouse gas emissions (Steinfeld et al., 2006).

Moreover, meat consumption in large parts of the medium and high-income countries has reached magnitudes which have negative impacts on human health. Diets rich in animal protein are associated with obesity (Popkin, 2002), cardiovascular diseases and strokes (Westhoek, 2014), and several types of cancer (Amine et al., 2002; McMichael, Powles, Butler, & Uauy, 2007; Pan et al., 2012).

Several studies have calculated the benefits of moving towards more plant-based diets. Tilman and Clark (2014) find that a vegetarian diet could reduce greenhouse gas (GHG) emissions from food production by 55% on the projected 2050 income-dependent diet. A transition towards more plant-based diets is assessed to reduce global food related GHG emissions compared with a reference scenario in 2050 by 29–70% (Springmann et al., 2016) or 60% (Weindl et al., 2017) while at the same time human mortality would drop by 6–10% (Springmann et al., 2016).

However, such studies do not answer how to promote a transition towards more plant-based diets. A first step in answering this question is to detect the main drivers of the consumption of meat. In this paper, we identify and assess factors influencing meat consumption, which may help to understand the present situation, anticipate future trends and be of importance for the identification of possible remedies (including policy interventions) to slow down the expected future rise. Our analysis distinguishes between total meat consumption and ruminant meat consumption, allowing thus to detect whether there are specific drivers underlying the evolution of the consumption of ruminant meat relative to the other types of meat (mainly pig and poultry meat). Ruminant, pig and poultry meat differ in terms of GHG emissions as

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LCA analyses estimate higher carbon footprints to meat from ruminants because of the emissions from enteric fermentation (Gerber, Mottet, Opio, Falcucci, & Teillard, 2015; Herrero et al., 2013; Nijdam, Rood, & Westhoek, 2012). Ruminants also have more negative effects on biodiversity (Machovina, Feeley, & Ripple, 2015) and on human health (Springmann et al., 2016). Furthermore, the variables differ in the resources needed for their production and may vary as well in cultural diet preferences.

The method we use is a cross-country regression analysis with data from 137 different countries, where we estimate the coefficients for a range of different variables affecting per capita meat consumption. Using a linear model such as ordinary least square (OLS) allows us to analyse the current state, and estimate the impact of the different influential factors, when controlling for other factors. The method has advantages compared with econometric assessments with a smaller number of explanatory variables, which will have a tendency of overestimating their effect on meat consumption. While previous quantitative assessments mostly focused on income and prices as drivers of meat consumption (e.g. Bodirsky et al., 2015; Huang & Lin, 2000; Muhammad, Seale, Meade, & Regmi, 2012), our study extends to a wider range of economic, social and biophysical drivers of meat consumption, and thereby provide a more comprehensive analysis of what causes rising meat consumption. Drivers of meat consumption have already been examined and assessed through econometrics in existing literature, but many are focussing on a specific regions, and few studies exist that explain meat consumption not only by country-specific price and income elasticities, but that consider further economic, social and environmental factors. Vranken, Avermaete, Petalios, and Mathijs (2014) includes several social and geographical variables, but does not consider prices, cross-prices or environmental variables in their model. York and Gossard (2004) include geographical and environmental factors but neglect, apart from income and urbanisation, all economic and social parameters. In this paper, we consider a broad range of potential drivers of meat consumption, based on the existing literature, and we cover the whole world (cross-country regression). Our main contribution is thus to provide a more comprehensive analysis of the drivers of meat consumption all over the world. Furthermore, we propose a ranking of the various drivers allowing for comparing, on a consistent basis, their respective impact on meat consumption.

The outline of the paper is the following: After a short insight to the historical development of meat consumption (section 1), we give a broad overview of the main drivers of meat consumption, which have been identified in the existing literature (section 2). We then detail our data and the applied method (section 3), before the obtained results are presented (section 4) and discussed (section 5).

2. Meat consumption and production development 1961–2011

Looking at different world regions (Africa, Asia, Latin America, Middle-East and North Africa and Western countries), data from FAO show that meat consumption per capita increased from 1961 to 2011 in all regions (Fig. 1).

Looking more closely at the different types of meat, we see that the growth in global meat production has been much stronger for pig and poultry meat than for cattle (Fig. 2).

3. Drivers for increased meat consumption

In addition to population growth, several factors have been identified in the literature as important drivers for increased meat consumption. They relate to four categories: economic factors, natural endowment factors, social factors and globalisation factors.

3.1. Economic factors

Among the economic factors contributing to increased meat

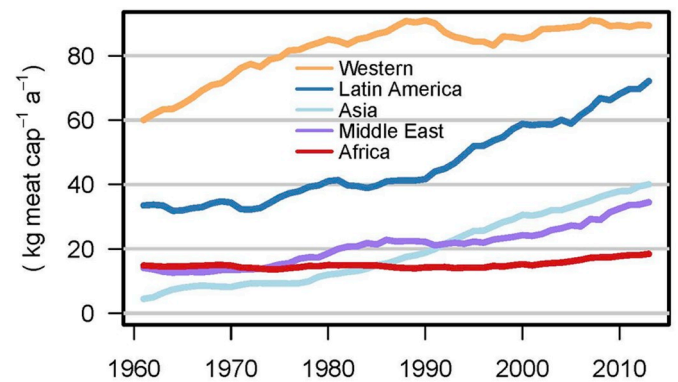


Fig. 1. Per-capita meat consumption ($\text{kg meat cap}^{-1} \text{ year}^{-1}$) has increased in all world regions from 1961 to 2011 (FAOSTAT). The country data are average weighted by population into 5 world regions.

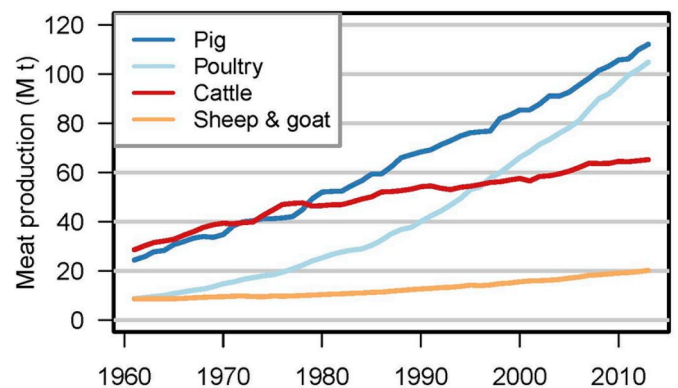


Fig. 2. The global production of pig and poultry meat has increased faster than that of ruminant meat from cattle, sheep and goat in the period 1961 to 2011 (FAOSTAT).

consumption, income is often mentioned. During the last 50 years, there has been an overall increase in income per capita in most countries in the world. For the developing countries this has led to, as a first step, an increase in the total amount of food consumed per capita (the “expansion” effect) and, as a second step, a change in the composition of the diet (the “substitution” effect) (Schmidhuber & Shetty, 2005). The second step reflects a shift from carbohydrate rich staples (cereals, roots and tubers) to vegetable oils, sugar and foodstuffs of animal sources (Ibid). These changes in diets, also observed in the developed world in prior periods, relate to the so-called “nutrition transition”, as described by Popkin (1993). Cole and McCoskey (2013) find in an econometric analysis of 150 countries that national meat consumption increases with higher incomes, and only reaches a point of inflection at a per capita annual income of US\$36,375, which in 2009 was the case for only eight countries in the world. A similar inverted u-shaped curve for the relationship between meat consumption and income is found in Vranken et al. (2014) and Bodirsky et al. (2015). As countries are at different stages of economic development, they are located at different points along the u-shaped curve and therefore income growth leads to different meat consumption responses across countries. A study by Regmi and Meade (2013) finds that income growth leads to larger increases in meat and dairy expenses in poor countries in Sub-Saharan Africa and South Asia than in wealthy countries such as the United States. Similarly in a study by York and Gossard (2004), it was found that the effect of income growth on meat consumption is stronger in both Middle Eastern and African countries than in Western countries, but not in Asian countries.

Relative prices are also important drivers which can accelerate or alleviate the speed of the observed nutrition transition. From the 1960s

to the early 2000s, there was a decline in the prices of livestock products relative to the prices of other products (FAO, 2009). This was enabled by technological change, scale efficiency gains and increased access to cheap inputs in livestock production sectors. Thus, animal-based food became more affordable even for those consumers who did not experience a rise in their incomes (FAO, 2009). According to the individual consumer theory, meat consumption increases (decreases) if the price of meat decreases (increases) more than price changes of other food products, all else being unchanged. In a meta-analysis of estimates of the own-price elasticity of meat demand obtained in 419 studies, Gallet (2010) finds that meat demand responds negatively to meat price, but is most often inelastic (i.e., own-price elasticity lower than 1). Within his sample, the median price elasticity estimate is -0.71 for aggregated meat, with the highest absolute value level obtained for lamb meat (-0.94), the lowest for poultry meat (-0.65). The median price elasticity estimate for aggregated meat is the highest (in absolute value) in Australia (-1.07) and the lowest in South America (-0.46).

Prices of food items which may substitute meat in a country's average diet may also influence meat consumption levels. When the price of a substitute increases, meat consumption may subsequently increase as well. Previous studies of food cross-price elasticities from Pakistan and Turkey find evidence that both vegetables, pulses and bread can act as substitutes for meat products (Hayat, Hussain, & Yousaf, 2016; Sahinli & Fidan, 2012).

3.2. Natural endowment factors

Differences between countries in their natural endowment influence their domestic production capacity for livestock products and can also cause a divergence in meat consumption between countries.

Data from FAO show that in 2011 most countries are still to a large extent self-sufficient for livestock products. In consequence, national per capita meat consumption and per capita meat production are closely correlated (Fig. 3). Correlation between domestic consumption and domestic production usually comes with a low share of imports and exports in domestic markets. Indeed, if a country can easily import from abroad in case of excess domestic demand or export in case of excess domestic supply, the correlation between domestic consumption and

domestic production should be weaker. There are various reasons explaining why in the case of meat, there is close correlation between domestic production and domestic consumption: diverging food safety standards of livestock products are trade barriers, and food safety and protectionist policies work against international trade. Transport costs for livestock products are generally higher than for crops, and the complexity of building up a cooled international food supply chain for animal products is very high and requires large investments and a professional bureaucracy (Henson & Loader, 2001). Thus, exporting excess supply on international markets or importing excess demand from abroad is likely more expensive for meat than for many crops and crop products. This may explain why international trade volumes generally account for a lower share of world production for meat than for major crops and crop products (according to FAO data, in 2011 the share of world imports in world production was about 15% for each type of meat – bovine, pork and poultry – while it reached 25%–35% for e.g. wheat, soybean, soy oilcake and raw sugar). This may also explain why the correlation between domestic consumption and domestic production is particularly strong in low-income countries and slightly weaker for high-income countries, the latter being able to adapt more easily to situations of excess demand or supply by utilizing world trade.

Due to this limited role of international trade in meeting excess supply or excess demand on domestic meat markets, domestic resource endowment, which influences domestic production capacity, also directly influences domestic consumption of animal-based products. Favourable production conditions will be reflected in low prices of animal products, but transmission channels may also go beyond market mechanisms: animal producers may lobby for favourable policies and influence consumer preferences through advertisements (Bogueva, Marinova, & Raphaely, 2017). We can also assume that countries which traditionally are meat producers, to some extent, have developed a culture for appreciating meat, which will be reflected in their per capita consumption levels.

Important natural endowment factors for livestock production include land availability and a favourable climate. As feed cultivation and grazing land for livestock require large land areas, land scarcity can be expected to discourage livestock production in general and grazing animals in particular (York & Gossard, 2004). Colder or very hot climate hinders the production of enough feed for animals, and therefore likely creates constraints to meat production. In their study, York and Gossard (2004) find that people living in temperate zones, on average, eat more meat than people in tropical and arctic/subarctic zones, and they connect this to the suitability of the temperate zone for grain production, which is necessary for the intensive production of meat.

3.3. Social factors

According to the existing literature, there are differences in meat consumption levels between countries that cannot be explained by any of the above mentioned economic or natural factors. We classify these as social factors. One such factor is urbanisation. Previous studies have found that the more urbanised a population is, the more meat is being consumed (York & Gossard, 2004). Possible explanations are that people in cities consume more food away from home and larger amounts of pre-cooked convenience foods than people in rural areas (Schmidhuber & Shetty, 2005). They also have better access to modern mass media and are more exposed to advertisement, and are therefore more influenced by globalized trends such as Western, more animal-based diets (Popkin, 2006). Urban areas also have better transportation systems and larger supermarkets dominated by multinational corporations, with better possibilities for maintaining the cold chain for animal-source products (Popkin, 2006).

Female participation in the workforce is another potential driver for the nutritional transition and towards meat consumption. In many countries, since the 1960s, women's participation in the workforce has increased significantly. Today there are substantial differences across

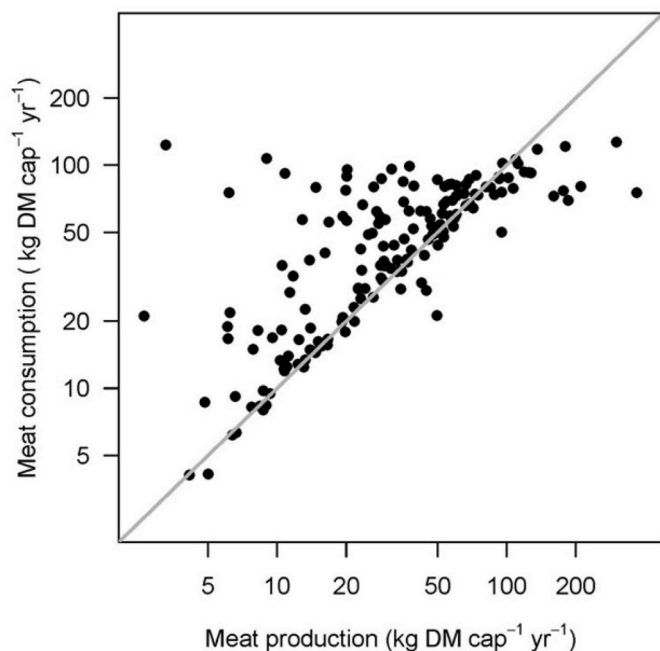


Fig. 3. Countries' per capita meat production and consumption, 2011 (log scale, one-to-one line in grey). Source: FAO food balance sheet.

countries in the percentage of adult women who have paid work outside the household. Female participation in the workforce has a potential influence on the composition of the household diet, as it may lead to the consumption of more convenience food which is faster to prepare (Connor, 1994; Manrique & Jensen, 1997; Schmidhuber & Shetty, 2005).

Furthermore, it seems clear that culture affects the different countries' consumption patterns, and that the history and traditions of a country play an important role, influencing what is seen as superior or inferior food (de Boer, Helms, & Aiking, 2006; Leroy & Praet, 2015). Also religions have a potentially strong impact on diet patterns: Muslims and Jews are forbidden to eat pork, Hindus should not eat beef, and Buddhists belonging to certain branches should restrain from meat eating altogether.

3.4. Globalisation

Globalisation, meaning more cross-border movement of capital, technology, goods, services, people and information has been advocated as a driver of dietary changes (Popkin, 2006 e.g.). However, there is no consensus on the link between globalisation and dietary changes. Oberländer, Disdier, and Etile (2016) explain that case studies tend to show that trade and foreign direct investment (FDI) lead to a convergence of national food systems. This development in turn contributes to diet changes in line with the nutrition transition, hence towards more consumption of meat. However, some theoretical models as well as empirical studies lead to less conclusive results. Oberländer et al. (2016) show that there is no significant impact of so-called economic globalisation (i.e., trade and FDI openness) on the amount of energy derived from animal products (including meat) in diets. However, so-called social globalisation (i.e., personal contacts with foreigners, information flows and cultural proximity) causes a 20% increase in the amount of animal sourced-energy in diets (Oberländer et al., 2016). This indicates that convergence of diets is more related to the induced cultural convergence mechanisms than to the more pure economic aspects of globalisation.

4. Data and method

In order to identify the importance of different drivers for meat consumption, we use data at national level for all countries and years in which the selected variables are available. The resulting data set includes values from 123 countries for the year 2005 and 137 countries for the year 2011. These are the only two years for which price data from World Bank International Comparison Programme (ICP) are available. We chose two different dependent variables: firstly, the total amount of meat consumed per capita ($\text{kg meat capita}^{-1} \text{a}^{-1}$) and, secondly, the amount of ruminant meat (beef and veal, mutton, lamb and goat) consumed per capita ($\text{kg meat capita}^{-1} \text{a}^{-1}$).

We summarize the sources of the data used for the analysis and describe the statistical methods applied.

4.1. Data

Data on annual meat consumption per capita are from FAOSTAT (Food Balance sheets and Population data, FAO, 2016). Based on the previous overview of the determinants of meat consumption, we use a range of different factors as explanatory variables (Table 1).

Economic factors are accounted for by income and relative prices. Our income variable is the purchasing power adjusted gross national income (GNI) per capita from the UN. We also include the square of the same variable to capture non-linear effects on meat consumption, especially for higher income levels. Average per capita income levels sometimes do not fully reflect the development state of a country, so we also include the non-income related UN human development indicators (HDI) for each country. This variable contains data on life expectancy,

years of schooling and expected years of schooling. We consider several relative prices, all extracted from the purchasing power parity adjusted consumer price data from the World Bank International Comparison Programme (ICP). These are the prices of meat as an aggregate, ruminant meat, monogastric meat and vegetables, all from the same data source and divided by the food price index. We include the price of monogastric meat as a substitute for ruminant meat, and fresh vegetables as a proxy for the prices of foods which can substitute meat in general in the consumers' diets. We recognise that we also could have used the price of other foods such as cereals or vegetal proteins (pulses), but aggregated price data for these items are not available at ICP.

Natural endowment factors are represented through per-capita land availability and climatic variables. The indicator for land availability is the inverse of the population density, derived from FAOSTAT. In order to control for climatic differences we include binary variables according to the countries' latitudes. Countries are divided into high latitude (north of 50°N or south of than 50°S), mid latitude (between 30°N and 50°N and between 30°S and 50°S), and low latitude (between 30°N and 30°S).

Social factors include an urbanisation variable, which is the share of urbanised population derived from FAOSTAT. We also include a female labour participation variable from the International Labour Organisation. In addition, we have included for each country the percentage of adherents to Islam¹. Data on religion are from the Association of Religion Data Archives. We have also included a dummy for countries belonging to the Western regions. This dummy will capture other aspects than the ones we are already controlling for, such as culture and traditions.

The globalisation variables are indicators developed by the KOF (Konjunkturforschungsstelle of ETH Zurich) and are computed for each country. The economic globalisation indicator is based on data on international trade and foreign investment flows as well as trade policy and financial regulations. The social globalisation indicator is based on data on interpersonal globalisation (e.g., incoming and outgoing telephone traffic, international tourism, international students, migration), information flow (e.g., used internet bandwidth, internet access, television access) and cultural globalisation (e.g., trade in cultural goods, international trademarks) (Gygli, Haelg, & Sturm, 2018).

The summary statistics for the different variables are depicted in Table 2 for all the available countries from which a complete subset is taken for the regression analysis. For simplicity we show the summaries for 2011.

The correlation matrix for all the variables used in the analysis (Table A1 in appendix) shows that there is medium to strong correlation (correlation coefficient above 0.5) between meat consumption and many of the potential drivers. The correlation is in most cases stronger for total meat consumption than for ruminant meat consumption.

4.2. Estimation methods

As our aim is to estimate the impact of different drivers on the contemporary meat consumption levels, and not to create a forward looking model projecting future demand for meat, a simple Ordinary Least Square (OLS) regression model is adequate for this purpose. However, in a regression analysis, the inclusion of the price of meat (total and ruminant) into the estimation equation for meat consumption may pose a problem of reverse causality: price may influence meat consumption, but meat consumption levels may also influence price. Thus, it is possible that the meat price ratios in our total meat demand and ruminant meat demand equations are not independent from the error terms. In this case, the OLS estimation gives inconsistent estimates. We therefore decided to test for the endogeneity (i.e., correlation

¹ We also tested for other religious group variables (Christians, Buddhists, Hinduists, etc.) but did not find any significant impact.

Table 1
Variables selected for the regression analysis and their sources.

Variable	Source	Reference & date of download
Total and ruminant per capita meat consumption	FAO Food Balance Sheets FAO Annual population	http://www.fao.org/faostat/en/#data , 19.10.2016
Relative prices of meat and vegetables	World Bank International Comparison Programme	http://www.worldbank.org/en/programs/icp#5 , received 02.06.2014 (data for 2005) and 05.09.2014 (data for 2011)
Purchasing power adjusted Income (GNI) per capita	UN	http://data.un.org/Data.aspx , 17.03.2015
Non-income related human development indicators (HDI)	UN	http://hdr.undp.org/en/composite/HDI , 06.06.2014
Land area per capita	FAO Land use	http://www.fao.org/faostat/en/#data/RL , 14.10.2016
Share of population urbanised	FAO Annual population	http://www.fao.org/faostat/en/#data/OA , 25.02.2014
Labour force participation rate, female (% of female population aged 15+)	International Labour Organisation	http://databank.worldbank.org/data/home.aspx , 28.03.2018
Share of population adhering to Islam	Association of Religion Data Archives (ARDA)	http://www.thearda.com/ , 13.03.2015
Economic and social globalisation	KOF globalisation index	https://www.kof.ethz.ch/ , 12.03.2018

Table 2
Summary statistics for all countries 2011.

Variable name	Obs	Mean	Std. Dev.	Min	Max
Total meat consumption per capita (kg a ⁻¹)	137	48	30	4.1	127
Ruminant meat consumption per capita (kg a ⁻¹)	137	14	11	1	68
Meat price ratio	137	1.1	0.2	0.5	1.9
Ruminant meat price ratio	137	1.0	0.4	0.4	2.6
Monogastric meat price ratio	137	1.3	0.3	0.8	2.4
Vegetable price ratio	137	0.8	0.2	0.3	1.4
GNI (PPP adjusted, current international 1000\$ capita ⁻¹)	137	16	16	0.7	85
GNI squared	137	532	968	0.5	7191
HDI non-income related	137	0.7	0.2	0.3	1.0
Country area per inhabitant (10 km ² capita ⁻¹)	137	4.4	8.4	0.1	56
High latitude	137	0.1	0.3	0	1
Low latitude	137	0.6	0.5	0	1
Medium latitude	137	0.3	0.5	0	1
Western	137	0.3	0.5	0	1
Urbanised population share	137	0.6	0.2	0.1	1
Muslim population share	137	0.2	0.3	0	1
Female participation (%)	137	41	8	14	53
Economic globalisation index	137	57	16	21	89
Social globalisation index	137	61	18	23	90

with the error terms) of the total and ruminant meat price variables in the total and ruminant meat consumption equations. For that purpose, we needed good instrument variables. We first tested the agricultural area per capita variable as instrument, with the idea that countries with high comparative advantages for meat are countries that can produce meat at a lower cost and should exhibit lower meat prices. We also tested regional averages of relative prices of meat with the idea that the relative price of meat in a specific country should be highly correlated with the average price of meat in the region this country belongs to. We retained a regional average price calculated for 15 world regions which we defined based on geographic and market integration factors². For each country, the regional average price of meat (total and ruminant) is calculated using the corresponding prices of all other countries belonging to the same region.

We applied the Durbin-Wu-Hausman test for endogeneity of the relative price of total meat and ruminant meat, using successively the agricultural area per capita and the truncated regional average meat

² The 15 regions are the following (with the number of countries belonging to the region in brackets): EU15(15), EU28(13 new EU Member States + 4 candidate countries from Former Yugoslavia), RestOECD(9), Former Soviet Union(9), East Asia (10), South Asia (7), Middle East-North Africa(15), Latin America(11), Central America(16), Western Africa(13), Central Africa(6), Eastern Africa(7), Sahara(4) and Southern Africa(13).

price as instrument. In both cases the null hypothesis was not rejected, which means that we cannot detect endogeneity of the price variable, and which indicates that OLS estimation is a consistent method. We thus decided to use OLS, and for the analysis we used STATA 15.0. To control for heteroscedasticity (i.e., the possibility that the variance of the error term in each equation is not constant across the observations) we use robust standard errors.

In order to estimate the relative importance of different drivers, we calculated measures following the guidebook by Nathans, Oswald, and Nimon (2012). These measures indicate in several ways how relevant changes within the explanatory variables are for changes in the predicted variable. The measure “ β -weight” explains the reaction of the predicted variable to changes in the explanatory variables in terms of standard deviations giving the change of the predicted variable when the explanatory variable is changed by one standard deviation. The structure coefficient “ r_s ” isolates the direct effects of the explanatory variable from the joint effect of all explanatory variables. It is calculated by quantifying the bivariate correlation between the explanatory and the predicted values in isolation from other explanatory variables. The correlation coefficient “ r ” describes the correlation between the explanatory and the predicted variable again in isolation from other explanatory variables. The Pratt's product measure is calculated by multiplying the β -weight and r and thereby reflects both direct and total effects. The communality coefficients give insight into how much of the influence of single explanatory variables is shared with the other drivers. They partition the variance caused by all explanatory variables into the “Unique” contribution of the respective variable and the “Common” contribution with any other combination of the explanatory variables.

5. Results

Estimation results were derived with OLS for both total meat and ruminant meat consumption per capita equations, and for both 2005 and 2011 (Table 3). The coefficients of determination (R^2) suggest that the overall fit of our specification is higher for total meat (0.89 and 0.86 for the 2005 and 2011 samples respectively) than for ruminant meat (0.68, 0.58).

5.1. Factors influencing total meat consumption

We consider estimation results for the year 2011 first and compare them with those for the year 2005. The estimation results clearly show that economic factors matter when analysing total meat consumption across countries: the meat price ratio has a significant negative impact on total meat consumption per capita in 2011. A doubling of the meat price relative to the general food price goes along with an average decrease in meat consumption per capita per year by approximately –17.8 kg. The coefficient of the vegetable price ratio is positive but not

Table 3

Regression results for total and ruminant meat consumption per capita as dependent variables for 2005 and 2011. Coefficients (coef), significance levels (SL) and standard deviations (SD) are given. Significant factors are denoted in blue for positive effects and in red for negative effects.

Variable name	Total meat						Ruminant meat					
	2005			2011			2005			2011		
	Coef	SL	SD	Coef	SL	SD	Coef	SL	SD	Coef	SL	SD
Meat Price (rel.)	-23.5	***	6.4	-17.8	**	6.0						
Ruminant meat price (rel.)							-10.0	**	3.3	-7.8	*	3.5
Monogastric meat price (rel.)							0.8		2.9	6.5		4.2
Vegetable price (rel.)	8.6		7.5	5.6		6.5						
GNI per capita	1.2	**	0.4	1.6	***	0.4	0.5	*	0.2	0.4	°	0.2
GNI per capita squared	-0.004		0.0	-0.01	*	0.0	-0.002		0.0	-0.002		0.0
HDI non income related	16.7		11.8	9.4		15.4	8.9		8.1	12.9		9.1
Area per capita	0.2	°	0.1	0.2		0.2	0.5	***	0.1	0.5	**	0.1
High latitude	-10.2	*	4.2	-13.1	***	3.6	-6.4	**	2.1	-7.5	**	2.8
Low latitude	-2.2		3.2	-1.5		3.6	-4.2	°	2.3	-5.7	*	2.4
Urbanised population share	32.1	***	8.0	33.2	**	9.5	8.6		5.8	11.5	°	5.9
Muslim population share	-9.7	**	3.5	-9.0	**	3.1	-1.0		1.9	0.1		1.9
Female participation	0.2		0.2	0.4	*	0.2	0.1		0.1	0.3	*	0.1
Western	17.3	**	4.9	8.9	°	5.0	-0.4		2.9	-1.4		2.7
Economic Globalization	0.03		0.1	-0.2	*	0.1	-0.1	°	0.1	-0.1	°	0.1
Social Globalization	0.1		0.2	0.4	*	0.2	0.04		0.1	0.03		0.1
Constant	0.6		14.2	-5.6		13.2	3.5		8.7	-12.0		10.1
R ²	0.89			0.86			0.68			0.58		
N	123			137			123			138		

Significance levels: '****' denotes $p < 0.001$, '***' < 0.01 , '**' < 0.05 , '*' < 0.1 .

significant. Income per capita has a significant positive impact on annual meat consumption per capita. This impact is slightly non-linear in 2011, indicated by the small but significant negative coefficient of the per capita income-square variable. The consumption response to a +1000 USD income per capita rise is thus close to +1.6 kg per capita, whatever the initial level of the income. According to our regression results, the non-income related Human Development Index (HDI) has no significant impact on annual total meat consumption per capita.

Among the natural endowment factors (area per capita, low and high latitude), high latitude significantly affects total meat consumption per capita. In line with previous studies, we find that people living in high latitudes eat on average less meat per capita per year than people living in medium latitudes (-13.1 kg). Contrary to expectations, land availability per person (area per capita) was not a significant driver of total per-capita meat consumption in the year 2011, while in 2005 a positive coefficient was significant, indicating that with land availability the livestock consumption increases.

Social factors clearly play a role in driving total meat consumption. The urbanisation rate has a significant positive impact on meat consumption per capita. Our regression results also confirm that religion plays a significant role regarding meat consumption per capita across the world, with a significant negative impact of the Muslim population share. Total meat consumption per capita responds positively and significantly to female labour participation. Equally, the dummy variable for being a Western country has a significant impact on total meat consumption per capita in 2011. At the same time, the coefficients for both economic globalization and social globalization are significant,

with an expected positive sign for the latter but an unexpected negative sign for the former.

The main difference between 2005 and 2011, among economic factors, is the relationship between total meat consumption per capita and income per capita, which is linear in 2005. Among social factors, there are two main differences. Firstly, female labour participation has no significant impact on total meat consumption per capita in 2005. Secondly, in 2005 total meat consumption per capita does not respond significantly to changes in both globalization variables, while the positive impact of the Western dummy is much more significant than it is in 2011. Hence, we may suspect that the three explanatory variables are collinear, meaning that they follow the same pattern. The correlation matrix for 2011 (Table A1) confirms that the three variables are highly positively correlated.

We ranked the different drivers of total meat consumption according to their explanatory power using the absolute values of their β -weights (Nathans et al., 2012). Compared with elasticities, β -weights have the advantage that they also account for differences in the variance of the different drivers. In both years, per capita income and urbanised population share are ranked first and third for their explanatory power (Table 4), respectively. Their importance is confirmed by Pratt's product measure and underlined by the highest commonality coefficients both for their shared contributions with other drivers (column 'Common') and for their unique explanatory power (column 'Unique'). In both years, a variable connected to high-income countries has second-most importance; for 2005 it is 'Western' and in 2011 the squared income. In general, the ranking of explanatory variables

Table 4

Coefficients for the contribution of the 5 most important driver variables for total meat consumption. Values are given for the β coefficients, Pratt's product measure and the Unique and Common commonality coefficients (in grey, explanatory variables with non-significant coefficients).

2005					2011				
Variable	β	Pratt	Unique	Common	Variable	β	Pratt	Unique	Common
GNI per capita	0,56	0,451	0013	0,646	GNI per capita	0,88	0,667	0024	0,550
Western	0,26	0,188	0015	0,526	GNI per capita squared	-0,44	-0,247	0011	0,306
Urbanised population share	0,23	0,170	0018	0,545	Urbanised population share	0,24	0,181	0022	0,547
Meat Price (rel.)	-0,18	-0,069	0016	0,133	Social Globalization	0,21	0,180	0005	0,693
GNI per capita squared	-0,11	-0,067	0001	0,346	High latitude	-0,15	-0,049	0014	0,095

reflects their importance and significance within the OLS regression giving a consistent picture of our findings (see also [tables A2](#) and [A.3](#) in the appendix).

5.2. Factors influencing ruminant meat consumption

Regarding the ruminant meat consumption per capita, our regression results suggest again that economic factors matter, but they are less important than for the total meat consumption equation. The ruminant meat price ratio has a significant negative impact on consumption per capita: a doubling of the ruminant meat price relative to the general food price goes along with an average decrease in ruminant meat consumption per capita per year by approximately 7.8 kg in 2011. The coefficient of the monogastric meat price ratio is positive but non-significant, indicating that our data do not show significant substitution between monogastric and ruminant meat within meat consumption. Income per capita has a significant positive impact on annual ruminant meat consumption per capita. This impact is linear, indicated by the non-significant coefficient of the per capita income-square variable. Therefore, there is no evidence of an inverted u-shaped curve between ruminant meat consumption and income per capita. Like total meat consumption, ruminant meat consumption per capita is not significantly responsive to the non-income related Human Development Index (HDI).

Natural endowment clearly plays a role for the consumption of ruminant meat. Area per capita positively and significantly affects the consumption of ruminant meat. Moreover, we find that arctic and subarctic conditions in high latitudes as well as tropical conditions in low latitudes lead to significantly lower consumption of ruminant meat per capita (−7.5 kg and −5.7 kg, respectively, relative to medium latitudes in 2011).

According to our regression results, social factors also drive ruminant meat consumption, but to a lesser extent than in the case of total meat consumption: estimated significance levels are lower and fewer variables have a significant impact. The urbanisation rate has positive but weakly significant impact on ruminant meat consumption per capita. Not surprisingly, the Muslim population share does not significantly influence ruminant meat consumption per capita across the world. Like total meat, ruminant meat consumption per capita responds positively and significantly to female labour participation. Finally, we do not find similar results as those obtained for total meat consumption regarding the Western dummy and the social globalization variable: neither variables significantly affect ruminant meat consumption per capita. The non-significant impact of the Western dummy on ruminant meat consumption is not so surprising since there is a number of non-Western countries showing high levels of ruminant meat consumption per capita (Argentina, Brazil, Paraguay, Uruguay and Kazakhstan for instance). We find again the unexpected negative and significant effect of the economic globalization variable on ruminant meat consumption per capita. Contrary to the case of the total meat consumption equation, the estimated effects of the globalization variables do not change between 2005 and 2011.

Generally, the estimation results do not differ strongly between 2005 and 2011. Social factors have less significant impacts in 2005 than they have in 2011: the urbanisation rate and the female rate participation have no significant impact in 2005.

Ranking the importance of drivers for ruminant meat consumption ([Table 5](#)), we find the same order for the top five explanatory variables in both 2005 and 2011. Income and area per capita explain by far the largest part of the variance in ruminant meat consumption. Ruminant meat price, high and low latitudes all have a similar and negative impact on ruminant meat consumption. Only area per capita has a strongly unique influence (see also [tables A4](#) and [A.5](#) in the appendix).

5.3. Differences between total and ruminant consumption

The main difference between the estimation results for total meat and ruminant meat consumption lies in the role of the natural factors, which have a much more significant impact on ruminant meat consumption than on total meat consumption. Our estimation results suggest that people living in high and low latitudes eat on average less ruminant meat per capita per year than people living in medium latitudes. In addition, population density has a negative and significant impact on ruminant meat consumption per capita. These last results indicate that ruminant meat consumption is still dependant on domestic production conditions, which is natural as ruminants rely more on grazing and the availability of pasture land than monogastric animals. It also indicates that ruminant meat markets are less integrated, and there is a smaller role for international trade in meeting excess supply or excess demand on domestic markets (see discussion).

6. Discussion

Our results give quantitative evidence to the existing literature on economic, social and environmental factors influencing the demand for meat. Meat demand increases with income, urbanisation, female participation, western culture, social globalisation and natural conditions favourable for meat production, while it falls with rising prices, Muslim population, economic globalisation and unfavourable natural conditions. To our knowledge, it is the first time this broad combination of explanatory variables has been used in a cross-country regression analysis of meat consumption.

Previous econometric assessments ([Bodirsky et al., 2015](#); [Huang & Lin, 2000](#); [Muhammad et al., 2012](#)) often considered a much smaller number of explanatory variables, usually prices and income. Thereby, they may have overestimated the effect of income on meat demand, as other explanatory variables such as urbanisation or female participation are strongly correlated with income. As we find both qualitative arguments in the literature as well as a statistically significant estimations that further explanatory variables play a strong role for meat demand, food demand models using just income and price elasticities should be applied with care ([Valin et al., 2014](#)). When income development does not align with other phenomena of economic development, such as urbanisation, social globalisation or education, models may provide inaccurate results. This may in particular be the case for short-term economic shocks, which strongly affect incomes but less the cultural and environmental factors.

It is surprising that we found a significant negative impact of economic globalisation on both total and ruminant per capita meat consumption, while social globalisation affects positively and significantly total meat consumption in 2011. However, these opposite effects are in line with the theoretical model developed by [Olivier, Thoenig, and Verdier \(2008\)](#), which predicts a different impact of commodity trade and social integration on identity values, meaning that while global social integration creates cultural convergence, economic globalization favours inter-country cultural divergence and within country homogeneity. The correlation matrix ([Table A1](#)) shows that both the economic and social globalization have strong positive correlations with total and ruminant meat consumption. The OLS regression results indicate that when controlling for other indicators of economic development, such as income per capita, urbanisation and female labour participation, the causal link between economic globalisation and meat consumption per capita becomes negative. The correlation matrix ([Table A1](#)) shows that the economic globalisation variable is strongly correlated with other economic development variables. It could be that once the impacts of these variables on meat consumption are accounted for, the economic globalisation variable does no longer add information and has no explanatory power. In such a case, however, the estimated coefficients of the economic globalisation variables would not be significantly different from zero. In our results, their significance levels are

Table 5

Coefficients for the contribution of the 5 most important driver variables for ruminant meat consumption. Values are given for the β coefficients, Pratt's product measure and the Unique and Common commonality coefficients.

2005					2011				
Variable	β	Pratt	Unique	Common	Variable	β	Pratt	Unique	Common
GNI per capita	0,68	0,398	0017	0,325	GNI per capita	0,56	0,271	0009	0,227
Area per capita	0,40	0,195	0131	0,101	Area per capita	0,35	0,163	0096	0,119
Ruminant meat price (rel.)	-0,24	-0,026	0026	-0,014	Ruminant meat price (rel.)	-0,26	-0,037	0028	-0,008
High latitude	-0,20	-0,039	0027	0,010	Low latitude	-0,25	0,093	0022	0,113
Low latitude	-0,19	0,072	0013	0,128	High latitude	-0,23	-0,032	0034	-0,014

medium but they cannot be considered as insignificant. A possible explanation for the estimated negative impact of economic globalization on meat consumption could be that global market integration implies focussing on production for exports, and as animal products are more challenging to both produce and export, exporters will prioritize plant-based products. What is being produced for export in turn influences the domestic consumption level, through economies of scale as well as advertisement, political lobbying etc. This explanation is in line with the theory of inter-country cultural divergence of [Olivier et al. \(2008\)](#).

The significant coefficient for the meat price confirms the results of many previous studies of the own-price elasticity of meat ([Gallet, 2010](#)), finding that meat consumption lowers with increasing meat price. We do not find any substitution effect between ruminant and monogastric meat. The reason could be that there are forces not accounted for, such as feed prices or government policies, driving both types of meat prices in the same direction. While we find that prices have a significant effect on meat consumption, we also find that this effect is not necessarily large. Other explanatory factors such as income, urbanisation and globalisation had in the past a much more pronounced effect on meat consumption than prices.

The positive impact of income on meat consumption is as expected. Our cross-country empirical results suggest a linear or almost linear relationship between income per capita and, respectively, ruminant meat and total meat consumption per capita, meaning that a 1USD increase in income per capita will induce the same amount of additional consumption in all countries. This does not mean however that meat consumption increases to the same extent in all countries over time and that our results contradict previous findings that meat consumption increases more in countries with a lower average income per capita (e.g. [Regmi & Meade, 2013](#)). Using the linear predictions of the total meat consumption per capita equation in 2005 and 2011, we find that predicted meat consumption increases by 4.6 kg between 2005 and 2011 for the 10% countries with the lowest income per capita, and decreases by 13 kg for the 10% with the highest income per capita, showing that meat consumption is, on average, increasing in the poorest countries, and decreasing in the richest countries. This result is robust when we compare the 25% countries with the lowest and the highest income per capita. It is also in line with actual meat consumption in 2005 and 2011. From our estimated model, we can see that the predicted increase in meat consumption in low-income countries is due to growth in income per capita, but also to growth in other variables such as urbanisation and social globalisation, which have likely been stronger in low-income than in high-income countries in this time period.

The estimated coefficient of the variable for non-income related Human Development Index is never significant. This variable encompasses life expectancy, years of schooling and expected years of schooling. One could expect that a high score on the Human Development Index is a sign that the distribution of income within the country is more egalitarian, and therefore would have a positive impact on meat consumption. But a higher level of education could also possibly be correlated with lower meat consumption levels ([Cirera & Masset, 2010](#)). Or high meat consumption levels could have adverse

health effects and thereby possibly affect life expectancy negatively. These diverging dynamics could perhaps explain why the variable is not significant. Another explanation is that the Human Development Index is highly correlated with globalisation variables and other economic development variables such as urbanisation ([Table A1](#)). Once these variables are controlled for, the HDI variable does no longer bring additional information and has no longer explanatory power.

The impact of natural endowment factors on meat consumption indicates that a country's production capacity determines its meat consumption patterns, in particular for ruminant meat. As the endowment factors are given entities that cannot be influenced by consumption levels, this suggests that it is not only increased meat demand which is the driving force for production, but that production is also to some extent determining what type and how much meat is being consumed in a country. The link between domestic demand and domestic production becomes less strong when countries have the possibility to import from abroad in case of excess demand or to export in case of excess supply. This mechanism could be the reason why the influence of the natural endowment factors, according to our results, is stronger on ruminant meat consumption than on total meat consumption. Such result suggests that ruminant meat markets are less integrated than monogastric meat markets at the world level, so that in each country total meat consumption depends less on domestic production conditions than ruminant meat consumption.

Our study highlights the complexity of the drivers behind meat consumption, which include economic, social, cultural and environmental factors. It supports that in order to reduce meat consumption, policy intervention could target meat prices. However, prices are not the major driver of meat consumption. We show that the major drivers (income per capita, urbanisation and, for ruminant meat, climate and population density) are not offering good opportunities for direct policy intervention. This original result suggests that mitigating the rise in meat consumption per capita would likely require to act indirectly on consumer's preferences and consumption habits to shape favourably the current links between meat consumption and its major drivers. The significant impact of urbanisation, female participation, social globalisation and being a Western country confirm the importance of lifestyles ([Swinburn et al., 2011](#)), culture and the need to reduce time spent on cooking meals. This indicates that increased availability and affordability of plant-based ready-made products that may replace meat could potentially influence consumption patterns. Likewise, policies directed towards media advertisement, information and education could be of importance.

Conflict of interest

The authors declare that they have no conflict of interest.

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Table A.4

Variable	β	rs	rs2	r	Pratt	Unique	Common
GNI per capita	0,68	0,71	0,50	0,59	0,398	0017	0,325
Area per capita	0,40	0,58	0,34	0,48	0,195	0131	0,101
Ruminant meat price (rel.)	-0,24	0,13	0,02	0,11	-0,026	0026	-0,014
High latitude	-0,20	0,23	0,05	0,19	-0,039	0027	0,010
Low latitude	-0,19	-0,46	0,21	-0,38	0,072	0013	0,128
Urbanised population share	0,18	0,71	0,50	0,58	0,102	0010	0,328
GNI per capita squared	-0,17	0,55	0,31	0,46	-0,076	0002	0,206
Economic Globalization	-0,16	0,49	0,24	0,41	-0,064	0008	0,157
HDI non income related	0,15	0,63	0,40	0,52	0,077	0003	0,270
Female participation	0,10	0,15	0,02	0,12	0,012	0005	0,010
Social Globalization	0,05	0,68	0,47	0,56	0,029	0000	0,317
Muslim population share	-0,03	-0,28	0,08	-0,23	0,008	0001	0,053
Western	-0,02	0,52	0,27	0,43	-0,007	0000	0,183
Monogastric meat price (rel.)	0,02	-0,05	0,00	-0,04	-0,001	0000	0,002

Table A.5

Variable	β	rs	rs2	r	Pratt	Unique	Common
GNI per capita	0,56	0,64	0,40	0,49	0,271	0009	0,227
Area per capita	0,35	0,61	0,37	0,46	0,163	0096	0,119
Ruminant meat price (rel.)	-0,26	0,19	0,03	0,14	-0,037	0028	-0,008
Low latitude	-0,25	-0,48	0,23	-0,37	0,093	0022	0,113
High latitude	-0,23	0,18	0,03	0,14	-0,032	0034	-0,014
Urbanised population share	0,22	0,67	0,45	0,51	0,113	0018	0,242
HDI non income related	0,20	0,63	0,39	0,48	0,097	0006	0,223
Female participation	0,17	0,18	0,03	0,14	0,024	0017	0,003
GNI per capita squared	-0,17	0,51	0,26	0,39	-0,064	0002	0,149
Monogastric meat price (rel.)	0,15	-0,05	0,00	-0,04	-0,005	0016	-0,014
Economic Globalization	-0,15	0,40	0,16	0,30	-0,045	0007	0,086
Social Globalization	0,06	0,63	0,40	0,48	0,028	0000	0,231
Western	-0,06	0,48	0,23	0,37	-0,021	0001	0,134
Muslim population share	0,00	-0,20	0,04	-0,15	-0,001	0000	0,023

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