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Economic growth, sustainable development and food consumption:
Evidence across different income groups of countries

VERSÃO DEFINITIVA APÓS DEFESA

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Resumo

O presente trabalho tem como motivação principal perceber as interações entre o consumo alimentar, crescimento económico e desenvolvimento sustentável. Considerando o elevado crescimento populacional e o acentuado crescimento do rendimento disponível, espera-se que a procura global por alimentos aumente. Não só no sentido de alimentar as populações, mas também de satisfazer uma nova necessidade por produtos densos em calorias e proteínas. Alimentos de pecuária como a carne estão relativamente associados a esta nova tendência, mas também ligados a fortes impactos ambientais e de saúde pública. Perante esta situação, a literatura sugere que o consumo de carne deva ser reduzido pelo benefício do ambiente e da população mundial.

Inspirado por estes factos, este estudo aplica uma análise empírica utilizando uma abordagem ARDL de curto- e longo-prazo, destacando uma análise dividida por 3 níveis de rendimento e recorrendo a um indicador de desenvolvimento sustentável, analisando assim o consumo alimentar, em destaque o consumo de carne maioritariamente abordado na literatura. Para além de abordar também o impacto de uma possível redução no consumo de carne, sugerida na literatura, no crescimento económico e desenvolvimento sustentável.

Após analisar perante diferentes níveis de rendimento e utilizando um indicador de desenvolvimento que considera o impacto ambiental, os resultados sugerem que o consumo de carne, crescimento económico e desenvolvimento sustentável contemplam diferentes relações conforme o nível de rendimento analisado e a perspetiva crescimento/desenvolvimento abordada. Em resumo, o consumo de carne promove o crescimento económico enquanto, por outro lado, prejudica o desenvolvimento sustentável. Evidenciando um dilema entre as duas perspetivas abordadas. Investigação futura é necessária com objetivo de entender quais a soluções mais eficazes, no sentido de não por em causa o crescimento, salvaguardando a componente de desenvolvimento sustentável.

Palavras-chave

Consumo alimentar, crescimento económico, desenvolvimento sustentável, consumo de carne, custos ambientais, abordagem ardl

Resumo alargado

O presente trabalho tem como motivação principal perceber as interações entre o consumo alimentar, crescimento económico e desenvolvimento sustentável. Com base na motivação, as questões centrais da investigação poderão ser apresentadas como: (1) confirmar o efeito positivo do rendimento no consumo de carne, observado na literatura, (2) perceber qual a relação do consumo alimentar, nomeadamente o consumo de carne destacado com maior relevância na literatura, no crescimento económico e no desenvolvimento sustentável, (3) analisar os resultados numa perspetiva de diferentes tipos de rendimento e, por último, (4) compreender qual o impacto da mudança de hábitos alimentares sugerida na literatura.

Com a intenção de analisar o impacto do consumo alimentar e a importância do tema em questão, realizou-se uma revisão exaustiva da literatura. Os artigos analisados evidenciam maioritariamente os efeitos do consumo de carne no ambiente através do esgotamento de terra para cultivo e água potável, a deflorestação para plantações de cultivo, os custos das mudanças climáticas associados aos gases efeito de estufa emitidos pelo setor, a perda de biodiversidade, a poluição do ar e da água devido ao uso intensivo de fertilizantes, etc. No seguimento, muitos autores também foram revistos pela sua análise sobre os impactos do consumo de carne associados à saúde pública. O aumento do risco de doenças não transmissíveis, como doenças cardiovasculares e pulmonares, alguns tipos de cancro, diabetes tipo 2, obesidade, entre outros, é associada a hábitos alimentares, principalmente o forte consumo de produtos pecuários, destacando as carnes vermelhas e processadas. Por outro lado, observou-se uma segunda tendência de trabalhos na literatura, especificamente autores que analisam os possíveis impactos de uma redução no consumo de produtos de pecuária e carne. Outros posteriormente discutindo sobre as possíveis abordagens normativas para a sua execução. No entanto, a perspetiva económica encontra-se em falta, e os impactos do consumo alimentar não são considerados nem antes nem após a mudança dietética proposta em benefício do ambiente e da saúde pública. Estes fatores criam a necessidade para a elaboração do presente estudo.

Depois de reorganizar a revisão exaustiva da literatura, os dados são abordados e os métodos posteriormente aplicados. Os países utilizados foram os disponíveis e a divisão por grupo de rendimento foi realizada com o objetivo de lidar com a questão da heterogeneidade e entender o impacto em diferentes níveis de rendimento.

Dando início à análise, o impacto do crescimento económico sobre o consumo de carne foi estudado, na medida em que a literatura já explora a relação. O efeito é positivo e, de facto, os níveis de rendimento restringem o consumo de carne, uma vez que um aumento no rendimento provoca um aumento no consumo de carne. Este é o principal motivo, além do

crescimento populacional, por detrás da recente tendência do consumo de carne, observado principalmente nas economias emergentes (aqui incluídas como alguns dos países de rendimento médio alto). Além disso, o estudo expande-se, analisando o efeito do consumo alimentar no crescimento económico. O esperado é que o consumo alimentar promova o crescimento económico. No entanto, devido às externalidades associadas ao setor, o efeito no desenvolvimento sustentável poderá não ser tão evidente. Assim, com o objetivo de capturar a perspetiva ambiental, foi aplicado um indicador de desenvolvimento sustentável. O ISEW é conhecido por capturar, para além da económica, as perspetivas sociais e ambientais. A presente análise capta as últimas através das componentes do ISEW, nomeadamente o índice Gini e alguns custos ambientais, em específico associados ao esgotamento de energia, minerais e florestal; e danos causados pelo CO2 no longo-prazo. Uma vez que o setor de alimentos e agrícola estão associados a muitas preocupações ambientais, o ISEW apresenta-se perfeitamente apropriado para a análise.

Uma análise estatística foi realizada antes da análise empírica. Os dados mostram a disparidade dos níveis e taxas de crescimento do consumo de carne nos últimos 50 anos, ao considerar diferentes níveis de rendimento. Nos países mais ricos com altos níveis de consumo de carne é observada uma tendência recente com sinais de diminuição a partir do início do século. As economias emergentes são apresentadas com altos aumentos durante o período analisado, evidenciando a influência das elevadas taxas de crescimento económico. Por fim, as regiões mais pobres não têm mudanças significativas ao longo do período, mantendo o consumo baixo.

Os efeitos de curto- e longo-prazo foram realizados aplicando a abordagem *Autoregressive Distributed Lag* (ARDL). Seguindo os procedimentos metodológicos habituais para compreender as características dos dados com o objetivo de realizar a análise mais adequada, concluiu-se que os estimadores Driscoll-Kraay e FE Cluster eram os mais apropriados considerando os fenômenos presentes nos dados. Heterocedasticidade, autocorrelação e *cross-sectional dependence* e *independence* foram observados nos diferentes modelos estudados.

Segundo os resultados. As principais conclusões são que o consumo de carne difere em termos de impacto ao considerar diferentes níveis de rendimento. Os países mais ricos que importam carne de regiões mais pobres e mais baratas são afetados negativamente em termos de PIB. Mas, enquanto os alimentos não são produzidos no país, as regiões mais ricas deslocam os custos ambientais para os exportadores. Por outro lado, os países que produzem e exportam beneficiam em termos económicos, embora negligenciando os custos ambientais não capturados pelo PIB, mas significativos no ISEW. No entanto, a falta de qualidade nos dados dos países mais pobres poderá estar a afetar os resultados desse grupo. Em geral, o consumo de carne introduz um dilema. Seja para produzir, sem considerar os custos ambientais, ou considerar uma abordagem mais sustentável, preservando os ecossistemas, mas reduzindo as taxas de crescimento económico. Soluções são necessárias para uma estratégia *win-win*.

Abstract

The major motivation behind the present study is to analyze the interactions between food consumption, economic growth and sustainable development. Considering that high population and income growths will lead the coming decades, an increase in global food demand is expected. Not only in terms of feeding the population but also to satisfy their recent needs of more calorie- and protein-dense foods. Livestock products such a meat are closely related to this trend, but also associated with impacts on the environment and public health. From land and water depletion, to greenhouse gases emissions and higher risks of non-communicable diseases. Therefore, an answer to this problem is needed. The literature suggests that meat consumption should be reduced for the sake of the environment and global population

Inspired by these facts, this study employs an empirical approach, analyzing through three income groups and applying a sustainable development indicator, analyze the interactions of food consumption, specially meat consumption as the literature highlights. And the impact on the economy of a possible reduction in meat consumption suggested by the literature.

By analyzing for different income groups and using a sustainable development indicator, our findings suggest that meat consumption, economic growth and sustainable development have different relationships considering income level. Succinctly, meat consumption promotes economic growth following the GDP, but neglects the sustainable development ISEW. Evidencing a dilemma between economic growth and economic sustainability. Further research is needed with the objective of further understand which solutions are more effective, as with the intent to promote growth, while considering the environmental perspective.

Keywords

Food consumption, economic growth, sustainable development, meat consumption, environmental costs, ardl approach

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List of Acronyms

ARDL	Autoregressive Distributed Lag
CIPS	Cross-Sectional Augmented Panel Unit Root Test
DK	Driscoll-Kraay Standard Errors
ECT	Error Correction Term
FE	Fixed Effects
FSP	Food Security, Protein
GDP	Gross Domestic Product
HIC	High-Income Countries
ISEW	Index of Sustainable Economic Welfare
MC	Meat Consumption
MLIC	Middle Lower-Income Countries
PBC	Plant-based Consumption
UMIC	Upper Middle-Income Countries
VIF	Variance Inflation Factor
XNI	Exports/Imports Index

1. Introduction

Some authors predict that by 2050 the world population will reach 9.7 billion (United Nations, 2017), contributing to almost 3 billion more mouths to feed. Not only that but, alongside it, worldwide wealth has been increasing for the past decades, especially both in emerging economies and developing countries. Combining these two aspects, population and wealth high growth rates, a serious shift in dietary habits is expected. Meat consumption has been a prioritized option when choosing what to eat, due mainly for its affordability and accessibility, and its nutrition value, a source of protein and B-complex vitamins. Despite the past growth, high-income countries (HIC) have halted the consumption of meat and its by-products and even reducing it as observed recently, however reaching at high levels, two to three times the world average. Moreover, emerging and developing economies are observed to be shifting their dietary habits through benchmarking the same animal-based calorie-heavy diets followed in the developed world. According to Vranken et al. 2014 world meat production has increased from 65 to 279 million tons in the last 50 years, an increase of more than 400%. This would not be a concern if the consumption of livestock products were not associated with a complex spectrum of contemporary issues. From the environmental perspective to public health and even food security.

Studies from different scientific areas have highlighted the relationships livestock production and consumption have on the environment through natural resources depletion, mainly land and water, environmental degradation, mostly in form of deforestation and loss of biodiversity, and the emissions associated with the sector. On the other hand, livestock, and mainly processed and red meats, have been associated with higher risks of non-communicable diseases (NCD), such as cardiovascular, some cancers, type 2 diabetes and obesity, as well with higher resistance rates from humans to antibiotics. Food security is also questioned in the way that the conversion of plant-based crops, used to feed livestock, for meat is debatable and considered by some authors inefficient, compared to other types of foods.

Although livestock products remain an important contribute to the subsistence of our contemporary societies for its nutrition properties, affordability and accessibility and, in part, for the culture rooted in our civilizations, as well as a source of income, as a consequence of its consumption, plant-based products are associated with several advantages, such as reduced greenhouse gases emissions (GHGEs) and natural resources depletion or contribute to a healthier life, with lower risks of NCDs. Due to globalization and an easier access to information, knowledge on the impact of certain consumptions have recently drawn fresh questions into the debate of sustainable living. And various targets and policies have been implemented in form of economic, social and legal instruments with the aim of meeting the commitment for more sustainable habits (Abadie et al. 2016; Leach et al., 2016; Lombardini & Lankoski, 2013).

While most of the studies have analyzed the impact of a diet change, mainly from a meat- to a plant-based, on the environment and health, it seems that a gap exists in linking such a change with the whole economy. As such, the objective of this study is to analyze the interactions between food consumption, economic growth and sustainable development. The literature already highlights the benefits of restricting meat consumption followed by an increase in plant-based foods consumption, but to promote such a shift it is crucial to understand the effects on a wider perspective and be sure that such a structural change in the rooted dietary habits of the population do not threat the economic growth and sustainable development of a country.

Before the empirical analysis, an exhaustive literature review was made to understand the impacts of meat consumption mainly on the environment and public health. The analysis of the effects of income on meat consumption was also observed in the literature and thus compared with the results of the present study. The empirical analysis is focused on a set of 78 worldwide countries divided into three groups, considering their level of income, namely, high-income countries (HIC), upper middle-income countries (UMIC) and middle lower-income countries (MLIC). The Autoregressive Distributed Lag (ARDL) approach is applied using the Driscoll-Kraay standard errors (DK) estimator due to the presence of contemporaneous correlation and cross-sectional dependence.

Globally, the findings support that food consumption differs in impacts on both the economic growth and sustainable development approaches. The results also support the idea that the food consumption derived from imports, negatively affects economic growth as expected given the impact of the importation. On the contrary, it preserves the sustainable development, once that the depletion of natural resources in the livestock sector occurs outside the borders. It is worthwhile to mention that for the exporter, the relationship ought to be reversed, i.e., developed countries by relocating their environmental burdensome to poorer countries, these, while benefiting economic growth, neglect sustainable development. Thus, a dilemma is observed between economic growth and sustainable development, considering food consumption.

In addition to the introduction, the remaining sections of this work are structured as follows: Section 2 extensively explores the literature review on the diet shift and the major effects on the environment and public health; followed by a review on the food-growth nexus, highlighting on the importance of meat efficiencies; and lastly, the relationship of income and meat consumption. The data and methods are displayed in Section 3. Section 4 interprets the empirical results. The discussion is provided in Section 5. And finally, Section 6 concludes and highlights the main findings. The references are presented in section 7. The appendix section follows in the end.

2. Literature Review

2.1. The Environmental Costs of the Agricultural/Food Industry

One of the big issues of the 21st century is definitely climate change (McAlpine et al. 2009). Climate change is associated with land and water degradation, air pollution, deforestation, loss of biodiversity, temperature rising leading to more droughts and heat waves affecting crop and livestock production, impairing growth yield and quality, and it is recognized as a major public health problem that will impact food security (Thornton et al. 2009; Nardone et al. 2010; Joyce et al. 2012; Vermeulen et al. 2012; Reynolds et al. 2014).

The primary cause of climate change according to Steinfeld et al. 2006 is the livestock sector, generating more GHGEs – 18 % CO_2 equivalent – than transport. Studies have emerged throughout the years trying to pinpoint the effects of the food industry on the environment. In terms of GHGEs, studies support that the food sector, specifically livestock, is the most GHG-intensive. These emissions are accounted directly through the usage/combustion of fossil fuels on farms, nitrous oxide from fertiliser production/application and methane emissions derived from ruminants, and indirectly through agriculturally induced land use change. Moreover, the whole process associated with the production, distribution and consumption of food to and by consumers aggregating manufacturing, processing, transportation, packaging, retail processes, cooking and waste, all contribute to the direct and indirect emissions of GHG (Berners-Lee et al. 2012; Hoolohan et al. 2013).

Reviewing some studies on the quantification of GHGEs, although results vary, conclusions remain the same. Vermeulen et al. 2012 conducting a review on climate change and food systems, claims that the latter contributes to between 19 to 29% of global anthropogenic GHGEs. From this share, agriculture is responsible for 80 to 89% of global food system emissions. Garnett 2011 and Tubiello et al. 2013 account for 30% of all the anthropogenic GHGEs from global food production, including direct impacts from agriculture (10-12%), fertiliser production, fuel use and land use change (6-17%). Suggesting that meat and dairy products are the most GHG-exhaustive food types, alongside Lesschen et al. 2011, Dagevos and Voordouw 2013 and Notarnicola et al. 2016 referring these products as the most energy-intensive and ecologically burdensome foods, having the largest absolute GHGEs. At the national level, overall emissions are levelled between 15 and 28% (Garnett 2011; Kim and Neff 2009; Audsley et. 2009). Additionally, Foley et al. 2011 advocate that agriculture is responsible for 30 to 35% of global GHGEs, mainly from livestock and rice cultivation, tropical deforestation and fertilisers. Olivier et al. 2005 suggest a more moderate share of 15% of total GHGEs from human activities is related to food production. In terms of livestock production, McMichael et al. 2007 states that it represented a fifth of total GHGEs, being responsible for nearly 80% of the emissions of the agriculture sector. An extended review on GHGEs, specifically nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) from crop production and fertilizer management is made by Snyder et al. 2009. The authors argue that there is an ongoing confusion over the role of fertilizer N on cropping system emissions of GHGs, since it can optimize crop yields, minimize the global warming potential (GWP) of emissions per unit of production and reduce the need for conversion of natural lands to agriculture. Although, the growing use of fertiliser is seen as a concern since, as studies indicate, more than 50%, related to the share not taken up by crops, is either lost through leaching or released into the atmosphere mainly as N_2O, damaging ecosystems and contributing to global warming (Vergé et al. 2007).

In Asia, it is accounted that about 50% of the total GHGEs come from agriculture (Vergé et al. 2007). In the case of Europe, a report from the European Commission (Tukker et al., 2006) concluded that the food chain is accounted for 31% of EU total emissions. Further stating that meat and dairy products are the group of foods carrying the greatest environmental burden (see Tukker and Jansen 2006), responsible for approximately 50% of food-generated GHGEs. Another study from the EC (Weidema et al. 2008) found that the consumption of meat and dairy products is responsible for 24% of the environmental impacts (acidification, global warming, nature occupation, etc.) from the total final consumption in EU-27. Bellarby et al. 2013 points out that livestock amounts to 12-17% of total GHGEs in 2007 for the same EU-27. In India, Pathak et al. 2010, following a LCA on 24 Indian food items, show that animal products, mainly meat and dairy, top the most GHG-intensive foods. Further implying that 87% of GHGEs from the food sector come from food production. On the other hand, agriculture is responsible for 18% of total GHGEs in India.

A study forecasting GHGEs (Fiala, 2008), indicates that by 2030 meat production will continue to be a large producer of GHG, accounting up to 6.3% of current GHGEs. Popp et al. 2010 assessing future anthropogenic agriculture GHGEs (excluding CO_2) projected that, if diet preferences remain constant at the level of 1995, global agriculture emissions will increase significantly until 2055. Emission intensities of developing countries being larger than those of developed countries, total GHGEs are expected to increase up to 50% in the next three decades, derived from animal products (Pradhan et al. 2013; Vergé et al. 2007). According to an assessment of the relationships between population growth and non-CO_2 GHGEs, van Beek et al. 2010 indicate that emissions are expected to increase significantly in coming years. Accounting for an on average increase of 151 and 148% for CH_4 and N_2O, respectively, by 2050. Furthermore, confirming a positive relationship between population growth and emissions from agriculture activities (see also Schneider et al. 2011). The assesment was focused on developing and in transition countries. As population and wealth grow, associated with a rising per capita caloric intake and changes on dietary preferences, so does the consumption of meat and dairy products, especially in Asia, Latin America and Africa. If present economic trends continue, significant pressure on natural resources such as land and water will increase. Reacting to these pressures, GHGEs associated with global land use will change drastically in the future (Lotze-Campen et al. 2008; Allievi et al. 2015; Gerbens-Leenes et al. 2010). Other studies assessing the relation between income and food consumption of livestock further reinforce the existence of a positive relationship (Rask and Rask 2011; Gerbens-Leenes et al. 2010; Skoufias et al. 2011; Schneider et al. 2011).

The loss of biodiversity is an urgent issue as well, since the expansion of agricultural land increases deforestation, resulting in the release of high levels of CO_2 (Steinfeld et al. 2006; Wirsenius et al. 2010; Machovina et al. 2015). In the Amazon forest 70% of previously forested land was converted to livestock use, in form of pastures, being the highest rate of deforestation (Steinfeld et al., 2006), further increasing nutrient runoff, soil erosion and biodiversity loss (Turner et al. 2007; Lambin and Meyfroidt 2011). Livestock threatens directly biodiversity by destroying previous habitats, contributing to the loss of species accounted for 50 to 500 times greater than prior rates found in fossil records (Steinfeld et al., 2006). Indirectly through climate change and global warming by affecting through numerous changes in the distribution and abundance of species, leading to potential declines and extinctions of many (Pimm et al., 2014). It is also known that a meat-intensive diet commonly observed in developed countries leads to a higher degree of inequality in terms of environmental services usage (White, 2000). Besides livestock, other issues such as climate change and infrastructural development have their own share on biodiversity loss (Alkemade et al. 2013).

2.2. The Public Health Risks associated with Food consumption

In addition to the environmental impacts, the increasing trend towards diets high in saturated fats, sugars and animal products also directly affects human health, causing a global public health concern (Lock et al., 2010; Tilman & Clark, 2014). According to studies in this field, the current diet is associated with increases in non-communicable diseases (NCDs) (Campbell et al. 1998; Campbell and Campbell 2006) including coronary heart disease, the world's leading cause of death, and certain cancers, especially in diets with high levels of red and processed meat (Bouvard et al., 2015; T. Huang et al., 2012; Pan et al., 2012). However, the consumption of processed meat has a higher impact on human health than unprocessed meat (Micha et al. 2012). The increase consumption of animal products is also closely related to higher rates of type II diabetes (Aune et al. 2009; Hu 2011; Micha et al. 2012; Pan et al. 2013) and with higher all-cause mortality rates (Singh et al. 2003; Pan et al. 2012). Vegetarian diets, and especially vegan, can suffer from deficiencies in B vitamins, mainly B12 (McDougall, 2002). Another main concern is the relation between the actual trends and the high rates of obesity, particularly in the youth and poor-income families (Drewnowski & Darmon, 2005; McMichael et al., 2007; Ng et al., 2014). If current dietary trends continue unchanged, public health costs are expected to increase significantly in the future (Drewnowski and Darmon 2005; Wang et al. 2011).

2.3. Food and economic growth

It is necessary to mention that there is no evidence of a food-growth nexus in the literature. Nevertheless, as with other nexuses such as the energy-growth nexus I think that, due to the importance food and respective diets have been given for the past time, either by their impacts on the environment and public health, or the recent increase trend of the demand of food products, the subject of the food-growth nexus might be important to analyse. However, food does not have the same characteristics as, for example, capital, labour or even energy (known drivers of growth), since it is not seen as a productive factor. Food does require resources, and some types of food require more than others. Specifically, natural resources such as land and water, and others like energy and labour to be produced. The efficiency issue of the agriculture/food sector has been studied in the literature and this could be the link between food and economic growth. Hereafter, the study briefly examines a review on the relationship food production has with natural resources use and understand its underlying (in)efficiencies. Followed by a review on the drivers of meat consumption, with major highlight on income.

2.3.1. Food (in)efficiency

The agricultural/food sector is a major contributor to natural resources scarcity, in the case, land and water, through its intensive use. Global food production occupies more than a third (33%) of the world's land. But within the sector, the most resource consuming is the livestock. Livestock is accounted to fill up 80% of all the agricultural land, as grazing land covers a total of 70% and 34% of global cropland is used to feed livestock (Garnett, 2011; Steinfeld et al., 2006; Wirsenius et al., 2010). Since livestock requires substantial amounts of feed grains to produce meat, a diet composed mainly of livestock products requires high levels of land use (Gerbens-Leenes and Nonhebel 2002; Gerbens-Leenes and Nonhebel 2005). Regarding the feed intake required to produce 1 kg of meat, the latter is considered the least efficient food, in terms of protein provided, in comparison to plant-based products (Wirsenius, 2003; Wirsenius et al., 2010). Beef may need up to 16 kg of feed per kg of meat, while chicken has a conversion of 2 to 1 (Westhoek et al., 2011). Reviewing LCAs de Vries and de Boer 2010 conclude that beef requires 2 to 5 times more land then pork and chicken. Producing the equivalent of 1 kg of beef required 27 to 49 m^2 of land. Compared to milk and eggs, the proportion increases by 10-25 times, respectively. In terms of protein, beef still required the largest amount of land, reaching between 144 to 258 m^2 for 1 kg of protein produced. Furthermore, following de Ruiter et al. 2017, the authors show that meat and dairy production are associated with up to 85% of the UK's total land footprint and that, further agreeing with latter authors, that only 48 and 32% of total protein and calories derive from livestock products. Alexander et al. 2015 suggest that future dietary changes from staple crops towards commodities with higher land requirements, as livestock products, will become the major driver of land use change. Further explaining in Alexander et al. 2016 that, if the world were to adopt the average USA diet, it would be needed more than 170% of land to satisfy the demand. Moreover, replacing up to 50% of livestock products with plant-based foods could achieve and reduction of 23% per capita use of cropland for food production (Westhoek et al., 2014). According to Pelletier et al. 2011 animal production regardless of type (livestock, fisheries, aquaculture) shows much higher levels of energy requirements compared to the crops analysed.

Moreover, freshwater availability is also being endangered by the intensive production of livestock, contributing as well to its pollution (Steinfeld et al. 2006; Hoekstra and Chapagain 2006; Khan and Hanjra 2009). Irrigated agriculture is the major consumer of water, accounting for about 80% of total water use (Molden, 2007). Furthermore, it is quantified that most irrigations systems are less than 50% efficient. The low efficiency is suggested by the fact that water is under-priced, leading to not optimal efficiency performances by irrigation systems, since savings in water do not translate into overall cost savings (Huang et al., 2013). Besides the low costs, a lacking knowledge and inappropriate management practices from farmers, observed in Syria, contribute as well to the issue of poor efficiency leading to more losses in water consumption (Yigezu et al., 2013). Livestock is a large consumer of water resources, appropriating 29% of the total agriculture water footprint. From this, a third is related solely to beef from cattle (Mekonnen & Hoekstra, 2012; Ran, Lannerstad, Herrero, Van Middelaar, & De Boer, 2016). Moreover, according to Steinfeld et al. 2006 livestock is directly responsible for over 8% of total human water use. The authors further state that it has implications on the replenishment of freshwater by reducing infiltration through compacting soil, lowering water tables, reducing dry season flows and degrading the banks of watercourses. This conversion, from feed crops to meat, also involves a large energy loss, making it, overall, very resource intensive (Horrigan et al. 2002; Elferink and Nonhebel 2007).

2.3.2. Income and meat consumption

Although the impact of meat consumption on economic growth has not been yet analysed in the literature, the inverse, i.e., the influence that income has on meat consumption, has been studied for the past decades. Influenced by the facts reviewed on the last section, meat consumption has been analysed mainly thru a "drivers of" approach, in the literature. As far as Kinnucan et al. 1997, proposing that the component of social instruments could have an impact on meat consumption, specifically through health information. The authors find that a change in health information given to the public has larger impacts than a change in prices. Socioeconomic status (SES) has been analysed as a factor of meat consumption as well. Education level, urbanization, age, gender, occupation have all been associated with different impacts to meat consumption (Clonan et al. 2016; Gossard & York, 2003). Nevertheless, a major contributor to meat consumption has been identified as economic growth. It is observed in the literature that HIC tend to have a significant higher consumption of meat products, however it is notable an increase in the emerging economies, especially in China and Brazil, and where urbanization is more felt (Clonan et al. 2016; Vranken et al. 2014).

3. Methodology

3.1. Data

The present analysis focuses on a dataset of a total of 78 countries. We divided the dataset into three groups based on the countries' economic development level, i.e., their income level according to the World Development Indicators' definition. The analysis extends to high-income countries (HIC) that include 35 countries, namely, Australia, Austria, Canada, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States of America and Uruguay. For the upper middle-income countries (UMIC) we have 23 countries, specifically, Argentina, Belarus, Brazil, Bulgaria, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Iran, Kazakhstan, Macedonia, Malaysia, Mexico, Panama, Paraguay, Peru, Romania, Russian Federation, South Africa, Thailand, Turkey and Venezuela. Finally, the lower middle- and low-income constitute a total of 20 countries and are designed as middle-lower income countries (MLIC) incorporating, Armenia, Bolivia, Egypt, El Salvador, Guatemala, Honduras, India, Indonesia, Kyrgyz Republic, Moldova, Nigeria, Pakistan, Philippines, Sri Lanka, Vietnam, Rwanda, Senegal, Sierra Leone, Tanzania and Uganda, where the last 5 are considered low-income countries. All the three groups use a balanced panel dataset. The number of countries and years in the analysis are due to data availability. Some countries from the 78 in total were excluded from the analysis due to gaps in the data but where considered in the descriptive analysis, the countries are mentioned further when the empirical models are assessed. The time-series spans from 1995 to 2013, forming a range of 19 observations for each country, resulting in a total of 665, 437 and 380 observations in HIC, UMIC and MLIC, respectively.

In order to analyse the interactions mentioned, and further compare between the economic growth approach and the sustainable development approach, four different models are conducted. Therefore, meat consumption is analysed with the conventional gross domestic product (GDP) and compared with the sustainable development index of sustainable economic welfare (ISEW). Afterwards, GDP and ISEW are analysed in terms of food consumption, i.e., the impact of meat and plant-based consumption on growth and development, and further compared. A comparison is also undertaken between the different income groups of the countries analysed.

The gross domestic product (GDP) is in constant 2010US$ and was retrieved from the World Development Indicators (WDI). Food consumption is analysed through meat consumption and plant-based consumption. Meat consumption is the aggregate of different types of meat: bovine meat, mutton and goat meat, pig meat, offal, poultry and other meat (FAO designation). On the other hand, plant-based consumption, also deployed in the analysis for a better understanding of the relationship between animal and plant-based products and in terms of growth and development, include four major food groups, namely fruits, vegetables, cereals and legumes that further consider food specific products such as tree nuts, starchy roots, pulses besides fruits, vegetables and cereals.

The study is conducted by considering the demand for food instead of the supply. Demand for food is obtained by subtracting from the domestic food supply the values of feed use, losses in the period before the food reaches consumers, food used for seed and other uses. That is:

consumption = (production + stocks + imports – exports) – feed use – losses – seed – other uses

Food consumption calculated through this method tends to overestimate consumption, as it is assumed that all the available food is actually consumed. However, since there is no value on the share of waste from households, as it varies over individuals and households, it is the most viable proxy of food consumption (Clonan et al. 2016; Vranken et al., 2014; York & Gossard, 2004). All the data on food consumption was retrieved from the Food and Agriculture Organization's (FAO) Food Balance Sheets (FBS). Table A.1., in the appendix, synthetises the variables definition and sources.

The ISEW is an index that, contrary to GDP, tries to measure the sustainable economic welfare. In theory, it is built upon a wide collection of three groups of data: economic, environmental and social. The construction behind ISEW begins with personal consumption expenditure which is weighted for income inequality to consider the disproportional advantages the rich have from the benefits of economic growth compared to the poorer countries. From this base, the calculus follows by adding and subtracting welfare positive and negative magnitudes, respectively. Education and health expenditure are two of the essential welfare favourable parameters added, while costs of environmental pollution, natural resources depletion, climate change associated costs, the cost of biodiversity loss, air and water degradation costs, among others are some of the welfare negative magnitudes subtracted (Bagstad et al. 2014). Other authors, like Beça & Santos, 2010 also include, besides the economic and environmental, some social factors such as the cost of unintentional accidents, the cost of crime, the value of household labour, the cost of leisure time, the cost of underemployment, the cost of a harmful lifestyle. However, it is rather difficult to measure this type of data since it implies an abstract concept of measurement and it might be quantified differently depending on the author. For example, the cost of a harmful lifestyle. Although some of the data exists, it is restricted to a small sample of high institutionalised countries. Some of the difficulties and benefits of the development and usage of the ISEW indicator are further described by Bleys & Whitby, 2015.

As it was mentioned above, due to lack of data for all the countries and years, some parameters are not used, such as the social indicators, since the large official databases such as the World Data Bank, OECD and Eurostat do not offer the full range of data, proposed in the literature, required for the ISEW. The succeeding formula describes the ISEW analysed in our study. Following the methodology by Menegaki & Tsagarakis, 2015, it follows,

$$ISEW = C_w + G_{eh} + K_n + S - N - C_s \quad (1)$$

where C_w represents the weighted private consumption, G_{eh} is the non-defensive public expenditure, K_n stands for the net capital growth, S incorporates the unpaid work benefit, N quantifies the depletion of the natural environment and C_s refers to the cost of social issues, which, as in Menegaki & Tsagarakis, 2015, were not included in the calculations due to lack of data. Table 1 briefly depicts the parameters and calculations of the ISEW, across all countries.

Table 1. ISEW type of components, variables, sign, calculus and data sources for all countries

Type	Variable	Sign	Calculus	Source
Benefits	A. Adjusted personal consumption with durables (Cw)	+	PC*(1-GINI)	PC: http://data.worldbank.org/indicator/NE.CON.PRVT.CD GINI: https://dataverse.harvard.edu/dataset.xhtml?persistentId=hdl:1902.1/11992
	B. Education Expenditure (Geh)	+	EE*0.5	http://data.worldbank.org/indicator/NY.ADJ.AEDU.CD
	C. Health Expenditure (Geh)	+	HE*0.5	http://data.worldbank.org/indicator/SH.XPD.PUBL
Benefits /Costs	D. Net capital growth (Kn)	±	GFCF-CFC	GFCF: http://data.worldbank.org/indicator/NE.GDI.FTOT.CD CFC: http://data.worldbank.org/indicator/NY.ADJ.DKAP.CD
Costs (environmental)	E. Damage associated with CO2 emissions (N)	-		http://data.worldbank.org/indicator/NY.ADJ.DCO2.CD
	F. Energy depletion (N)	-		http://data.worldbank.org/indicator/NY.ADJ.DNGY.CD
	G. Forest Depletion (N)	-		http://data.worldbank.org/indicator/NY.ADJ.DFOR.CD
	H. Mineral depletion (N)	-		http://data.worldbank.org/indicator/NY.ADJ.DMIN.CD

Notes: All the monetary data were deflated to 2010$ after the calculus, since current prices was the only available option in the WDI. The components following the definition are the ones used in Eq. (1). The Gini was applied as determinant of economic inequality (Gründler & Köllner, 2016). Only half of the expenditure in education and health is assumed to be defensive (Jackson et al. 1994).

It is worthwhile to make clear that in the computation of the ISEW, a few observations were calculated through growth averages due to the lack of data. For example, in the HIC, for Japan, information on the last two years was lacking for the ISEW indicator and so the growth rates for the past years were performed, summed all together and divided by the respective number of years, thus calculating the last two observations. In the UMIC, the same procedure was followed for Belarus, Kazakhstan, Malaysia and South Africa for the year 2013; and Iran and Thailand for the years 2012 and 2013. In the MLIC, the group with more information lacking, the countries Armenia, Egypt, Moldova and Philippines had the last year (2013) in fault. For India, Kyrgyz Republic, Nigeria, Pakistan, Vietnam, Senegal, Sierra Leone, Tanzania and Uganda the two last observations (2012 and 2013) were missing. Although, Rwanda, Sierra Leone and Uganda were not considered in the models but only in the descriptive analysis. Other countries with three or more gaps were immediately excluded from the sample.

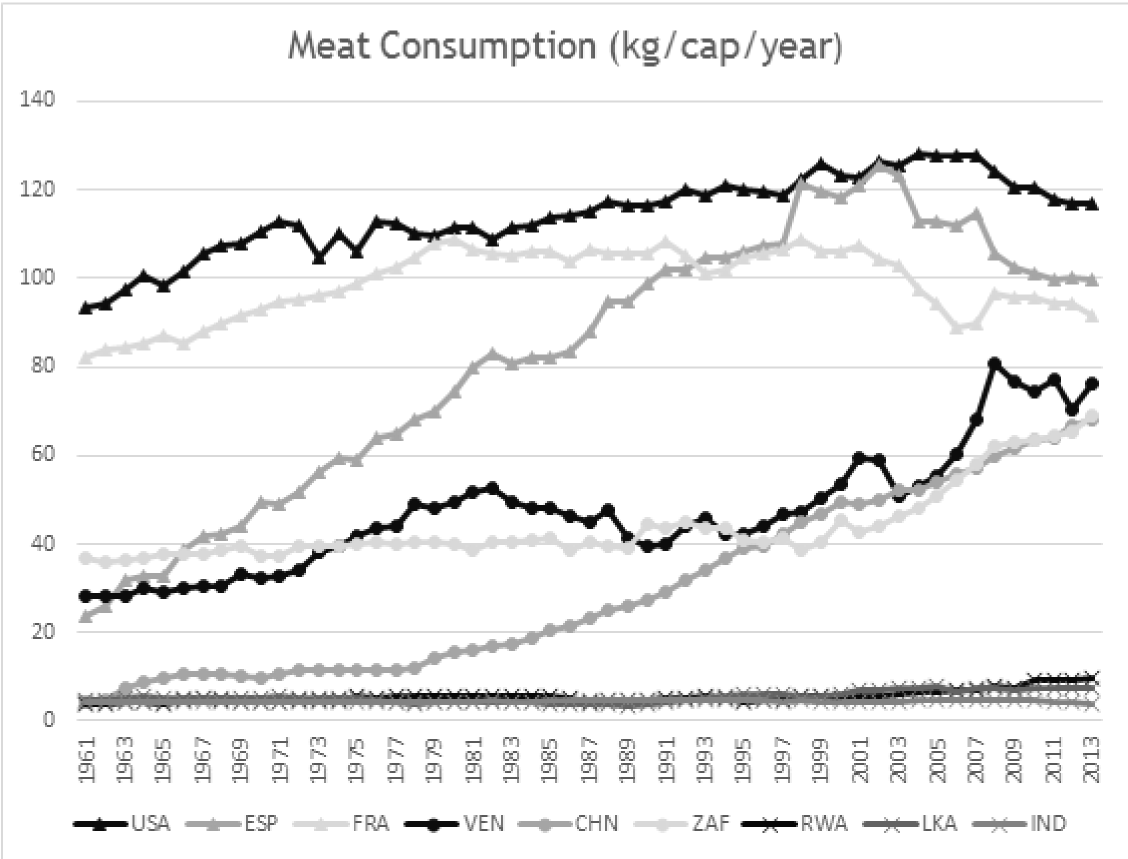
The methodology took into consideration in the study proceeds as follow: (1) the quality and nature of the data is observed; (ii) the issues of heteroscedasticity, serial correlation and contemporaneous correlation and cross-section dependence were assessed as well as the integration of the variables; (iii) since the study has the objective of analysing the short- and long-term interactions between food consumption, economic growth and sustainable development the ARDL approach is applied.

3.2. Descriptive Statistics

Following the established path, an initial analysis of the data is made. Putting the focus on meat consumption growth for the past 53 years, fig. 1 is provided. The figure corresponds to the three analysed groups of income and includes 3 countries of each. The triangle, circle and cross denote HIC, UMIC and MLIC, respectively. For the HIC the top three in terms of consumption in 2013 are displayed, for the UMIC, the three with the highest consumption rates for the whole period are analysed and for the MLIC, the bottom three least consuming countries are observed. Meat consumption is measured in kg/cap/year and the period goes from 1961 to 2013 for all countries.

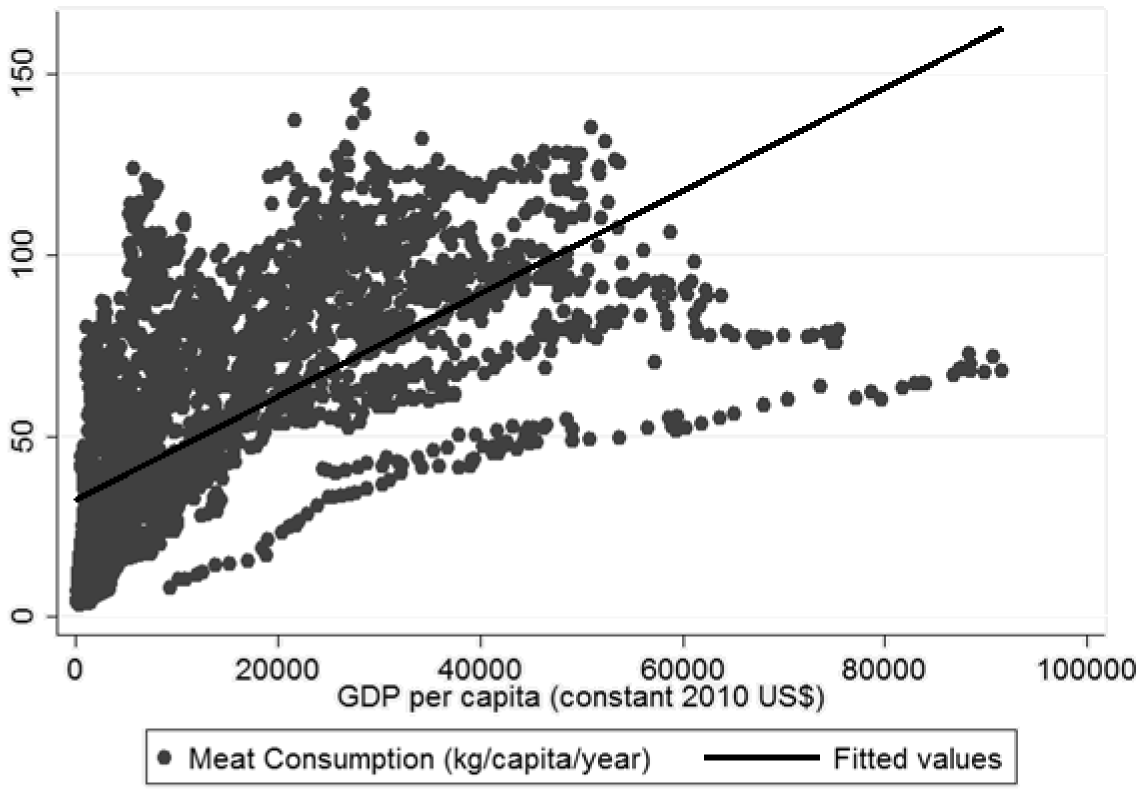
From the figure, some global tendencies can be observed. First, a big difference of consumption between the three groups is evident. The HIC have an annual consumption of more than 100 kg per capita per year on average, where the UMIC do not even reach the 80 kg per capita per year. A much smaller consumption is clear in the MLIC analysed, consuming less than 10 kg per capita per year. The United States of America is the major consumer in the figure alongside Spain and France. India, having the smallest consumption, is a special case due to the fact that the majority of its citizens follows a vegetarian diet. Other aspect that can be deduced from the figure is the recent decreasing trend observed in all three HIC analysed, since the beginning of the century. Contrary to the brutal increasing trends from the UMIC. The country with the highest increase is China, having more than quadrupled increased their consumption throughout the years. In Spain, it can be seen an increase from 24 kg per capita annually in 1961 to almost 100 kg per capita per year. As in Venezuela, from 28 to 76 kg per capita annually. While in China, a much dramatic increase is observed, from 4 kg per capita in 1961 to almost 70 kg per capita, an increase rate of more than 1500%. Although these dramatic increases exist in emerging economies, the poorer countries continue with lower levels of consumption throughout the years. Figures for the Sub-Saharan countries suggest broad differences in meat consumption between countries, with Nigeria, Rwanda, Sierra Leone and Tanzania on average below 10 kg per capita, around 15 kg per capita in Senegal and Uganda, in comparison with a meat consumption above 50 kg per capita, in recent years, in South Africa. Rwanda and the latter shown in the figure.

Fig. 1. Evolution of meat consumption in 3 countries of each income group, period 1961-2013



Furthermore, fig. 2 presents the relationship between meat consumption and income, for the overall sample. The main finding by observing the graph is that, in fact, income promotes meat consumption. We can see the massive dots in the left lower corner representing the poorer countries with small levels of meat consumption, in comparison with the more developed countries with higher levels of meat consumption. Therefore, by looking at the figure we can propose that, with higher levels of income, meat consumption increases, i.e., the relationship between income and meat consumption follows a positive linear framework. It can even be suspected that a possible negative quadratic framework, similar to Kuznets, 1955, exists. Moreover, it can be deducted that at certain level of income, meat consumption starts to decrease. This is intensively explored by Vranken et al., 2014 where the authors empirically test this hypothesis concluding that in fact an inverted-U follows the relationship between meat consumption and income. Due to the need of consistency in the objective of this work, the hypothesis proposed will not be analysed.

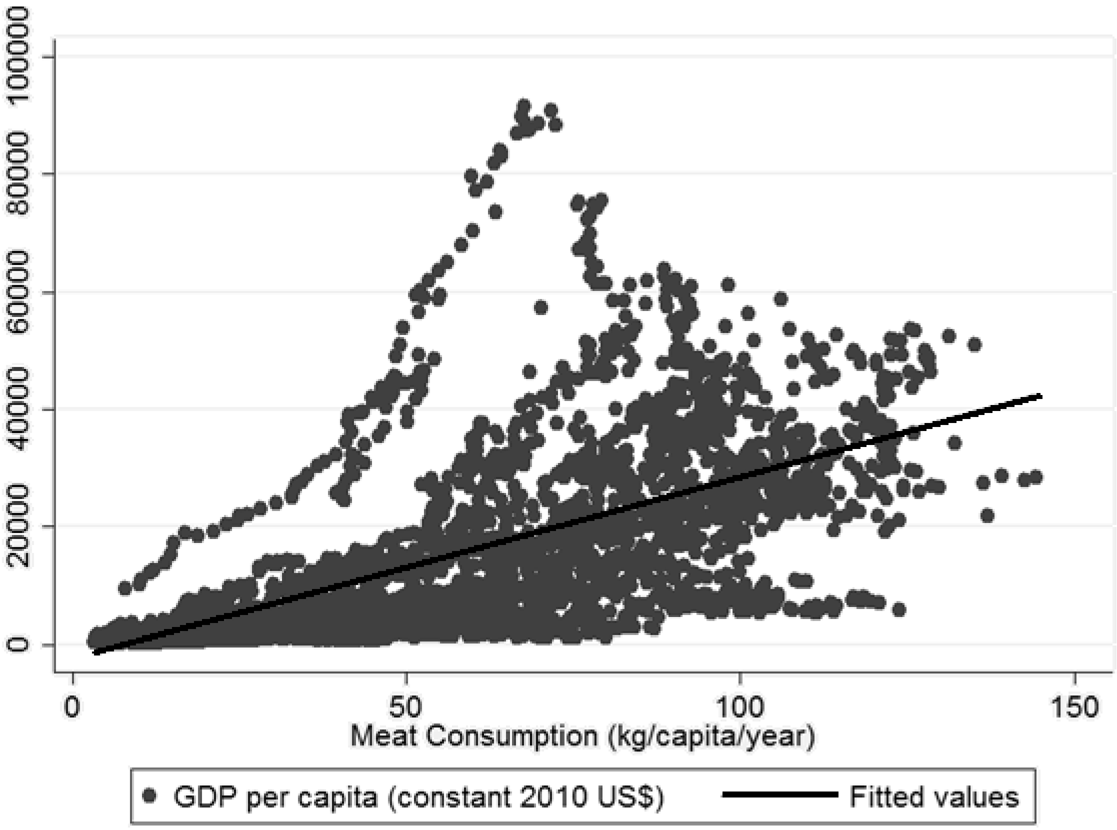
Fig. 2. Relationship between meat consumption and income per capita for all countries



Following our objective of studying the interactions between food, growth and development an additional figure is added to the analysis. Fig. 3 shows the relationship between income per capita and meat consumption. This perspective is new to the literature as discussed in sections above, but some findings can be directly highlighted through the figure below.

As it was observed in the following figure, at a first analysis it can be proposed a possible positive linear relationship between meat consumption and income, i.e., as meat consumption increases so does income, but at a lower rate, if compared to the inverse relationship. Although, the positive relationship can be observed, the graphic points out that there still exist many countries with reasonable levels of meat consumption but suffer from poor economic status. Others, on the other hand, with a relative increase in meat consumption see their economic level increase as well.

Fig. 3. Relationship between income per capita and meat consumption for all countries



To better understand the magnitude of meat consumption we can consider its average value for all countries, of nearly 60 kg per capita per year. By calculating the average meat consumption per day, we can understand the magnitude of the quantity consumed in our daily basis. Doing so, the average of meat consumption per day equals to 164 grams per capita.

According to McMichael et al., 2007, the authors suggest that in order to tackle the environmental degradation of the food industry a reduction to 90 grams per capita per day should be pursuit. Further explaining that to achieve such goal a reduction should be conducted in the developed world followed by an increase in meat consumption by the poorer countries. Comparing to the 90 grams per capita per day, the mean of the countries analysed is way much higher, almost the double. If we further compare by income level group we have a much higher meat consumption value of almost 85 kg per capita per year, giving a portion of 234 grams per capita of daily meat consumption in the HIC. More that the double compared to the goal proposed above. From this point, the mean values decrease, with a portion of 148 grams per capita of daily meat consumption in the UMIC and 60 grams per capita per day from the MLIC. From these only 27 grams per capita are consumed daily in the five LIC analysed. Overall, the disparity in consumption is very large. Considering the 90 grams per capita per day goal a reduction of more than half of meat consumption needs to be pursued in the developed world and a more than reasonable increase in the poorer regions.

3.3. Methods

Since the focus of this study is to analyse the interactions between food consumption, economic growth and sustainable development, and considering the recent concern with dietary habits and as a reference for future generations, it was decided to pursuit an analysis of the dynamic effects in the short- and long-run. The Autoregressive Distributed Lag (ARDL) has the characteristic of analysing both effects separately (Pesaran & Shin, 1999). Another advantage is its robustness in front of different integration order of the variables, i.e., I(0), I(1) or both, but not I(2). Considering two approaches, namely the economic approach and the sustainable approach, applying the GDP and the ISEW, respectively; and further analysing between different income groups, specifically HIC, UMIC and MLIC, twelve models were estimated. Table A.2. is provided with the models notations to further facilitate the analysis. The general specification of the ARDL models for a specific income level are as follows:

$$LMCPC = f(LGDPPC; LPBCPC; LFSP; LXNI; LKOF; LL; LCPI) \tag{2}$$

$$LMCPC = f(LISEWPC; LPBCPC; LFSP; LXNI; LKOF; LL; LCPI) \tag{3}$$

$$LGDPPC = f\ (LMCPC; LPBCPC; LFSP; LXNI; LEUPC; LKOF; LGFCFPC; LL; LCPI) \tag{4}$$

$$LISEWPC = f\ (LMCPC; LPBCPC; LFSP; LXNI; LEUPC; LKOF; LGFCFPC; LL; LCPI) \tag{5}$$

The empirical models, where the short- and long-run dynamics are presented, i.e., the ARDL equivalent of the general unrestricted error correction model (UECM), for the four panels are specified as follows:

$$\begin{aligned}\Delta LMCPC_{it} = \alpha_i &+ \sum_{j=0}^{n} \beta_{1ij} \Delta LGDPPC_{it} + \sum_{j=0}^{n} \beta_{2ij} \Delta LPBCPC_{it} + \sum_{j=0}^{n} \beta_{3ij} \Delta LFSP_{it} + \sum_{j=0}^{n} \beta_{4ij} \Delta LXNI_{it} \\ &+ \sum_{j=0}^{n} \beta_{5ij} \Delta LKOF_{it} + \sum_{j=0}^{n} \beta_{6ij} \Delta LL_{it} + \sum_{j=0}^{n} \beta_{7ij} \Delta LCPI_{it} + \delta_{1i} LMCPC_{it-1} \\ &+ \delta_{2i} LGDPPC_{it-1} + \delta_{3i} LPBCPC_{it-1} + \delta_{4i} LFSP_{it-1} + \delta_{5i} LXNI_{it-1} + \delta_{6i} LKOF_{it-1} \\ &+ \delta_{7i} LL_{it-1} + \delta_{8i} LCPI_{it-1} + \varepsilon_{it}\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta LMCPC_{it} = \alpha_i &+ \sum_{j=0}^{n} \beta_{1ij} \Delta LISEWPC_{it} + \sum_{j=0}^{n} \beta_{2ij} \Delta LPBCPC_{it} + \sum_{j=0}^{n} \beta_{3ij} \Delta LFSP_{it} + \sum_{j=0}^{n} \beta_{4ij} \Delta LXNI_{it} \\ &+ \sum_{j=0}^{n} \beta_{5ij} \Delta LKOF_{it} + \sum_{j=0}^{n} \beta_{6ij} \Delta LL_{it} + \sum_{j=0}^{n} \beta_{7ij} \Delta LCPI_{it} + \delta_{1i} LMCPC_{it-1} \\ &+ \delta_{2i} LISEWPC_{it-1} + \delta_{3i} LPBCPC_{it-1} + \delta_{4i} LFSP_{it-1} + \delta_{5i} LXNI_{it-1} + \delta_{6i} LKOF_{it-1} \\ &+ \delta_{7i} LL_{it-1} + \delta_{8i} LCPI_{it-1} + \varepsilon_{it}\end{aligned} \tag{7}$$

$$\Delta LGDPPC_{it} = \alpha_i + \sum_{j=0}^{n} \beta_{1ij} \Delta LMCPC_{it} + \sum_{j=0}^{n} \beta_{2ij} \Delta LPBCPC_{it} + \sum_{j=0}^{n} \beta_{3ij} \Delta LFSP_{it} + \sum_{j=0}^{n} \beta_{4ij} \Delta LXNI_{it} + \sum_{j=0}^{n} \beta_{5ij} \Delta LKOF_{it} + \sum_{j=0}^{n} \beta_{6ij} \Delta LEUPC_{it} + \sum_{j=0}^{n} \beta_{7ij} \Delta LGFCFPC_{it} + \sum_{j=0}^{n} \beta_{8ij} \Delta LL_{it} + \sum_{j=0}^{n} \beta_{9ij} \Delta LCPI_{it} + \delta_{1i} LGDPPC_{it-1} + \delta_{2i} LMCPC_{it-1} + \delta_{3i} LPBCPC_{it-1} + \delta_{4i} LFSP_{it-1} + \delta_{5i} LXNI_{it-1} + \delta_{6i} LKOF_{it-1} + \delta_{7i} LEUPC_{it-1} + \delta_{8i} LGFCFPC_{it-1} + \delta_{9i} LL_{it-1} + \delta_{10i} LCPI_{it-1} + \varepsilon_{it} \quad (8)$$

$$\Delta LISEWPC_{it} = \alpha_i + \sum_{j=0}^{n} \beta_{1ij} \Delta LMCPC_{it} + \sum_{j=0}^{n} \beta_{2ij} \Delta LPBCPC_{it} + \sum_{j=0}^{n} \beta_{3ij} \Delta LFSP_{it} + \sum_{j=0}^{n} \beta_{4ij} \Delta LXNI_{it} + \sum_{j=0}^{n} \beta_{5ij} \Delta LKOF_{it} + \sum_{j=0}^{n} \beta_{6ij} \Delta LEUPC_{it} + \sum_{j=0}^{n} \beta_{7ij} \Delta LGFCFPC_{it} + \sum_{j=0}^{n} \beta_{8ij} \Delta LL_{it} + \sum_{j=0}^{n} \beta_{9ij} \Delta LCPI_{it} + \delta_{1i} LISEWPC_{it-1} + \delta_{2i} LMCPC_{it-1} + \delta_{3i} LPBCPC_{it-1} + \delta_{4i} LFSP_{it-1} + \delta_{5i} LXNI_{it-1} + \delta_{6i} LKOF_{it-1} + \delta_{7i} LEUPC_{it-1} + \delta_{8i} LGFCFPC_{it-1} + \delta_{9i} LL_{it-1} + \delta_{10i} LCPI_{it-1} + \varepsilon_{it} \quad (9)$$

The prefixes "Δ" and "L" denote first differences and natural logarithms of the variables, respectively. The subscripts i, j and t denote country, lag length and time period, respectively. The intercept is denoted as α, β_i and δ_i are the estimated parameters, and ε_{it} the error term. The natural logarithms were applied to facilitate the interpretation of the elasticities and semi-elasticities, as they are presented as percentages and percentage points (pp), respectively.

In order to proceed with this panel data approach some characteristics are required in respect of the data. The presence of cross-sectional dependence is analysed by using the CD-test. Results revealed in tables A.3. – A.5. show that cross-sectional dependence is present, which could be explained by the income level proximity of the countries analysed within each income group. Considering the presence of cross-sectional dependence, determining whether the data is stationary or integrated is essential. To do so, second generation unit root tests CIPS (M. Hashem Pesaran, 2007) were applied. The results for each of the income groups are displayed in table A.6., in the appendix. By looking at the results we can observe that not all the variables are stationary in levels. Although, by applying the differences, we can conclude that all variables are stationary in first differences, thus confirming that the variables are all integrated of first order, i.e., I(1). As such, these outcomes confirm the appropriateness of the use of the ARDL approach. Additionally, multicollinearity between the variables was also tested using the variance inflation factor (VIF). The results show that the VIF values are all less than 5, suggesting that this issue will not be a problem.

In terms of the choice for the most efficient estimator, the Robust Hausman test (sigmamore option suggested by Cameron & Trivedi, 2010) to select between the fixed effects (FE) and random effects (RE) estimators was applied. The null hypothesis is that random effects is suitable instead of fixed effects. The null hypothesis is rejected in all the models following the results shown in tables 2-3, with at least 5% significance. Therefore, considering that the FE estimator is the most suitable for the present study. The possibility of a heterogeneous panel is not considered, mainly due to the fact that countries were grouped according to their income level. By doing so, the risk of being faced with a heterogeneous panel is severely reduced, as it can be considered that the cross sections share common coefficients.

From this point, additional specifications are required with the purpose to understand the robustness of the estimator. The presence of heteroscedasticity, autocorrelation and contemporaneous correlation among cross sections was analysed. The results of all tests are reported in tables 2-3.

Table 2. Specification tests

Models	I - MGHIC	II - MGUMIC	III - MGMLIC	IV - MIHIC	V - MIUMIC	VI - MIMLIC
Hausman test	90.76***	37.07***	77.23***	101.70***	43.88***	74.67***
Pesaran CD-test	0.814	-1.183	0.631	0.483	-1.357	0.72
Friedman CD-test	24.442	14.461	20.916	18.485	13.441	22.375
Wooldridge test	52.719***	18.515***	43.797***	55.163***	58.182***	17.787***
Modified Wald test	5480.09***	145.57***	408.7***	4974.3***	209.74***	670.45

Notes: The Hausman test has a χ^2 and tests H_0 that unobservable individual effects are not correlated with the explanatory variables; Pesaran and Friedman's test are parametric testing procedures and follow a standard normal distribution; The Wooldridge test is normally distributed N(0,1) and tests H_0 no serial correlation; The Modified Wald test has χ^2 distribution and tests H_0 no heteroscedasticity; Significance notation for 1, 5 and 10% are denoted as ***, **, *, respectively.

Table 3. Specification tests (cont.)

Models	VII - GMHIC	VIII - GMUMIC	IX - GMMLIC	X - IMHIC	XI - IMUMIC	XII - IMMLIC
Hausman test	57.5***	50.98***	48.61***	96.5***	82.86***	51.99***
Pesaran CD-test	20.657***	21.654***	26.268***	40.626***	39.223***	42.183***
Friedman CD-test	125.171***	125.707***	156.44***	243.907***	225.29***	243.296***
Wooldridge test	60.032***	80.64***	157.528***	108.044***	137.553***	143.606***
Modified Wald test	925.2***	1023.59***	6931.09***	4910.03***	1086.08***	3153.66***

Notes: The Hausman test has a χ^2 and tests H_0 that unobservable individual effects are not correlated with the explanatory variables; Pesaran and Friedman's test are parametric testing procedures and follow a standard normal distribution; The Wooldridge test is normally distributed N(0,1) and tests H_0 no serial correlation; The Modified Wald test has χ^2 distribution and tests H_0 no heteroscedasticity; Significance notation for 1, 5 and 10% are denoted as ***, **, *, respectively.

The phenomenon of group-wise heteroscedasticity was checked using the modified Wald test, developed by Greene, 2012. The null hypothesis of no heteroscedasticity present in the errors was rejected in all the models, suggesting that heteroscedasticity is present. Furthermore, the Wooldridge test (Wooldridge, 2010) detected the presence of autocorrelation in all the models as well, by rejecting the null hypothesis of no autocorrelation in the errors, with high significance, at the 1% level. For the appraisal of contemporaneous correlation among cross sections, two tests were conducted, the Pesaran test and the Friedman test. Both tests point out that not all the models suffer from the existence of contemporaneous correlation. Considering the results of the specification tests, two estimators were chosen for the regressions. The Driscoll and Kraay estimator (Driscoll & Kraay, 1998) was applied in the models where contemporaneous correlation was present, since the standard errors of the latter are robust in these conditions, alongside heteroscedasticity and autocorrelation. The FE model with robust standard errors was estimated in the models where contemporaneous correlation was not existent, considering only heteroscedasticity and autocorrelation. The results are analysed in the next section.

4. Empirical Results

The ARDL approach with the Driscoll-Kraay (DK) and the FE Robust with clusters are estimated for all the three income groups and respective analysis generating a total of twelve models. Once again, the analysis of this study is tripartite. The procedure involves (1) an analysis between income level groups is made under the same model, i.e., applying the same dependent variable, (2) a comparison is made within the same income level groups, i.e., an assessment between the conventional growth indicator, GDP, and the sustainable development ISEW and (3) an analysis is made around the interactions already mentioned by analysing both variables as explaining meat consumption and as explained by meat consumption. To preserve space, the reduced estimation results are presented in tables A.7. – A.10. in the Appendix. The elasticities and semi-elasticities are revealed on the next subsection.

Before analysing the impact of the parameters, the consistency of the models is observed. To evaluate whether the estimations are able to explain part of the variations in the dependent variables analysed, namely meat consumption, economic growth and sustainable development, the F-tests were performed for each estimation, testing for the joint significance of all the included variables. As it can be observed in tables A.7 – A.10. in the appendix, for all the models, the F-tests reject the null hypothesis, with the highest significance (1%), that there is no joint effect of the included explanatory variables. Thus, concluding that the included variables have some explanatory power for the changes in eat consumption, economic growth and sustainable development. Regarding the error correction term (ECT), which reveals the speed adjustment of the model given a specific shock. Considering an impact in the short-run, the ECT indicates how long is needed for the model to readjust. For example, in model (I - MGHIC) the ECT is of -0.3184, indicating that the time the models needs to adjust is a bit less than 3 years. Contrary to model (VII - GMHIC), which needs more than 10 years to adjust (-0.07913). To assess the magnitude of the effects, both semi-elasticities and elasticities were performed (tables 4-7).

4.1. Does income promote meat consumption?

From tables 4-5, the results of the analysis of meat consumption through the economic growth approach show that major statistically significances for food consumption, at least in the short- or long-run, for all countries. In table 4 the effects of economic growth on meat consumption are as expected. All income level groups showing a positive impact. The higher effect is observed in the poorer countries, although only in the short-run. The semi-elasticities can be read as, with a 1 percentage point (pp) increase in a certain variable, the dependent increases in the order of the elasticity of semi-elasticity value in pp terms. Therefore, a 1 pp increase in the GDP per capita follows a 0.614 pp increase in meat consumption in the MLIC, analysing the short-term. By doing the same analysis in the HIC and UMIC we have an 0.112 and 0.207 pp increase in meat consumption, respectively. Although with no statistically significance for the HIC, but at the 5% level for the UMIC. Larger impacts are observed in the long-run for both HIC and UMIC. The analysis of the elasticities is different, as a 1% increase in the parameter analysed contributes to an increase in percentage, of the value observed in the elasticity. Thus, the impacts are of 0.201% in HIC and 0.533% in UMIC. In terms of plant-based consumption, the expected is confirmed as well. In the developed countries, a negative effect is observed both in the short- as in the long-run. In the HIC an increase of 1 pp and 1% in plant-based consumption follows an impact of -0.287 pp and -0.407% in the short- and long-run, respectively. As it is seen in the UMIC, impacts of -0.133 pp and -0.45%, as in the above order. Although the latter not statistically significant.

Table 4. Semi-elasticities, elasticities and adjustment speed for MC with GDP, using FE Cluster

Models		**Growth Approach**	
	I - MGHIC	II - MGUMIC	III - MGMLIC
Semi-elasticities			
CONS	-1.0804174***	0.290925	-2.020108***
DLGDPPC	0.111686	.20694281**	.61481858**
DLPBCPC	-.28732295***	-.1332404**	
DLFSP	1.6512577***	1.1364022***	.56886743***
DLXNI			
DLKOF			-.01394144***
DLL	.19909584*		
DLCPI	-.23588953***	.03821618**	
Elasticities			
LGDPPC (-1)	.201217*	.5328088***	
LPBCPC (-1)	-.4068056***	-0.44965	
LFSP (-1)	2.016222***		2.224505***
LCPI (-1)	-.2281669***	0.0728851**	
ECT	-.31840031***	-.17700334***	-.32029882***

Notes: ECT means Error Correction Term. Significance notation for 1, 5 and 10% are denoted as ***, **, *, respectively.

In terms of food security, the supply of protein intake has a positive impact on meat consumption independently of the group analysed, as expected. The long-run effects are higher than the short-run, as it is suspected. Therefore, the impacts, in the short-run, of a 1 pp increase in this parameter follow an increase in meat consumption of 1.65, 1.14 and 0.569 pp in the HIC, UMIC and MLIC, respectively. Compared with the impacts of 2.02 and 2.22% in the long-run, in the HIC and MLIC, respectively. The variables assessing food trade dependence, globalization and labour reveal to be not statistically significant in the long-run. However, some impacts can be observed in the short-term such as negative influence from globalisation in the MLIC (-0.014). Labour only affects meat consumption in the HIC with a coefficient of -0.199, at a low level of 10% significance. Finally, the consumer price index has a negative and positive influence on HIC and UMIC, respectively, both in the short- and long-run but not evident in the poorer regions. The short-run impacts are observed in the UMIC with a positive semi-elasticity of 0.038, compared to the long-run elasticity of 0.073. Both are significant at the 5% level. In the HIC it is observed a negative influence in the short- as in the long-term of -0.236 and -0.228, respectively.

4.2. The influence of sustainable development (ISEW) on meat consumption

By replacing the conventional economic growth indicator, GDP, with the sustainable development indicator ISEW, the estimations in table 10 are presented. Instead of only taking into account the produce of a country, in this analysis, the ISEW incorporates the environmental perspective alongside the issue of inequality into its measurement. The results follow in the next table.

Therefore, conducting the analysis following the sustainable approach, i.e., by introducing the ISEW in the estimation, it can be observed that no major differences are detected. However, some findings can be highlighted. Through analysing the impact of ISEW in meat consumption we can observe that its influence is smaller compared to the impact observed with the growth approach. The effects decrease at least a quarter in all income groups, highlighting the highest different in the poorer countries. However, the signs remain the same. In the HIC, ISEW is not statistically significant in the long-run, although highly significant in the short-term, contrary to the growth approach analysis.

Table 5. Semi-elasticities, elasticities and adjustment speed for MC with ISEW, using FE Cluster

Models	Sustainable Approach		
	I - MIHIC	II - MIUMIC	II - MIMLIC
Semi-elasticities			
CONS	0.176103	-0.17232	-2.0832036***
DLISEWPC	.05197942***	.04300174**	.07682116***
DLPBCPC	-.26824212***	-.14289301**	
DLFSP	1.6505724***	1.2698515***	.67480636***
DLKOF		0.13016	
DLCPI		.0752162***	
Elasticities			
LISEWPC (-1)	0.061782	.0577246**	
LPBCPC (-1)	-.259742**	-0.48061	
LFSP (-1)	1.882159***	1.28311***	2.152145***
LKOF (-1)	.3387401**	0.233252	.0285622***
LL (-1)	-.3041277**		
LCPI (-1)	-.1336256***	0.1256206***	
ECT	-.3234561***	-.23544957***	-.34357598***

Notes: ECT means error Correction Term. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

Another major difference is the observed globalisation positive influence (0.029) in the MLIC in the long-term, contrary to the negative influence in the short-run for the GDP analysis. A significant (at 5%) elasticity is observed as well from the globalisation parameter in the HIC, in the long-run (0.339). Also in the HIC, the labour parameter enters the regression with a negative impact, observed in the long-term, 1of a -0.304 decrease in meat consumption, opposing the short-term positive impact visible in the GDP analysis. Apart from these major differences the remaining variables differ little in value and significance with no signs change.

4.3. Could meat consumption be an economic growth driver?

Analysing from a different perspective, to further understand the interactions proposed, economic growth is now analysed via meat consumption. Some results are expected but not supported in the literature as the latter were. The significance levels shown in tables 6 and 7 for the food consumption variables are highly significant at least in the short- or long-run, apart from meat consumption (10%) and plant-based consumption (not statistically significant) for the HIC. The same method from latter tables was followed for the not statistically significant parameters. Therefore, the influence of meat consumption on economic growth varies by income level group. In model VII meat consumption is negatively impacting only in the long-run, at the 10% level. This is also visible in model VIII, but at the high 1% level. On the contrary, for model IX the impact of meat consumption is shown to be positive in the short-run. A 1% increase in meat consumption will decrease economic growth by nearly -0.125% and -0.371% in HIC and UMIC, respectively. While in MLIC this change is rather positive up to 0.882 pp in the short-run. Plant-based consumption is not statistically significant in HIC, neither in the short- nor the long-run, while it is observed a positive impact only in the short-run in the UMIC and MLIC of almost 0.08 and 0.11 pp, respectively.

Table 6. Semi-elasticities, elasticities and adjustment speed for GDP, using DK-FE

Models	Growth Approach		
	VII - GMHIC	VIII - GMUMIC	IX - GMMLIC
Semi-elasticities			
CONS	.41409567***	-0.12145	.88176731***
DLMCPC			.07113068***
DLPBCPC	0.020279	.07996857***	.11063895***
DLFSP			.14362202***
DLXNI			0.003373
DLEUPC	.11567683***	.1532725***	.07180224**
DLKOF	.06446164**		
DLGFCFPC	.19850145***	.1692263***	.10274556***
DLL	.26562181***	.13898085**	
DLCPI		-.03629212***	
Elasticities			
LMCPC (-1)	-.1246816*	-.3710245***	
LPBCPC (-1)	0.118041		
LFSP (-1)		.8239693***	.5232198***
LXNI (-1)			.034003***
LEUPC (-1)	0.4286776***	.468237***	
LKOF (-1)	0.9659729***	.6450572***	
LGFCFPC (-1)	0.2833239***	.2249909***	.3067751***
LL (-1)	-.3398919**		-.1829077*
LCPI (-1)			.2638811***
ECT	-.07912935***	-.12962144***	-.16793378***

Notes: ECT means error Correction Term. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

The effects of the other estimated parameters on economic growth are also heterogeneous across the different regions. The food security proxy has a positive impact in the UMIC and the MLIC, but with no significance in the HIC. The impact is higher in the poorer countries with an almost 0.15 pp increase in the short-run. In the long-run the increases are of nearly 0.824 and 0.523% in the UMIC and MLIC, respectively. The dependency of imported food proxy has a minimum impact only in the MLIC with no apparent significance in the other groups. The impact of globalization is observed but only in the developed world, with a 0.064 pp and 0.966% increase in the short- and long-run, respectively, in the HIC. While in the UMIC the effects are only observed in the long-run with an 0.645% increase.

Following the productive factors analysed, except for labour in the long-run, all are observed to positively impact economic growth, as expected. The results are interpreted as above.

4.4. Meat consumption impact on sustainable development

Recalling that the objective of using the development approach is to capture the issue of inequality and the environmental associated costs of economic growth, changes are expected when assessing the two approaches as the food sector is known to be associated with environmental degradation. Table 7 presents the results of the analysis of economic growth following the ISEW as the dependent variable.

Table 7. Semi-elasticities, elasticities and adjustment speed for ISEW, using DK-FE

Models		**Sustainable Approach**	
	X - IMHIC	XI - IMUMIC	XII - IMMLIC
Semi-elasticities			
CONS	-3.7218551***	1.57637	2.114892***
DLMCPC	.09813813***		.47668071***
DLFSP		.95760311***	
DLXNI	-.02497877**		
DLEUPC		.68292605**	
DLKOF		-.5947049**	-.03533103***
DLGFCFPC	.93331736***	.75844851***	.44275011***
DLL			.9533598**
DLCPI	-.73777017**		-0.75002
Elasticities			
LMCPC (-1)		-2.088821*	1.030652***
LPBCPC (-1)	-.5354558***	-1.909022**	.8257031***
LFSP (-1)	0.70377	3.610375	-1.774136 ***
LXNI (-1)	-.1013955*	0.115539	
LEUPC (-1)		.8604905***	-.7349723*
LKOF (-1)	1.232738**	-1.16257	-.146868***
LGFCFPC (-1)	1.058583***	1.438439***	1.006348***
LL (-1)	0.988746	-0.57027	
LCPI (-1)			-.2662787**
ECT	-.18878645***	-.1814335***	-.30824661***

Notes: ECT means error Correction Term. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

Major differences can be highlighted. The long-run influence in HIC is lost due to a loss in significance, although in the short-run is observed a new impact at the 1% level. Meat consumption is positively influencing ISEW, i.e., a 1 pp increase in meat consumption in the short-run contributes to an increase of 0.098 pp in the ISEW. Contrary to the negative impact in GDP in the long-run. The other income groups remain with the same signs although the impact is higher with ISEW. In the UMIC the impact is nearly of -2.09%, though the significance falls to the 10% level, in the long-run. A positive influence remains in the MLIC, although the value is higher (0.477), compared to the growth approach (0.071), in the short-term. Meat consumption is observed to influence positively in the long-run (1.03), contrary to the not statistically significant effect in the growth approach. Following plant-based consumption, this is not statistically significant in the short-run, compared to the GDP analysis. However, in the long-run the influence is negative for both the developed groups and positive in the poorer countries, specifically -0.535 for HIC, -1.909 for UMIC and 0.826% for MLIC. The latter is observed to be not statistically significant in the growth approach.

In terms of the remaining variables, the more relevant changes are mainly observed in the fluctuations from the short- to the long-run and vice-versa. However, some signs change as well. Observing the food security parameter, it changes to a negative impact (-1.774) in the long-run for the MLIC, conflicting with the positive effect present in the growth approach for the same group. A new finding is observed in the HIC for the trade dependency, as it shows a negative impact both in the short- as in the long-term of -0.025 and -0.101, respectively. The latter at the 10% level. The globalisation index enters negatively in the regression for both the UMIC and MLIC in the short-run and only MLIC in the long-run. A high semi-elasticity is observed in the UMIC as nearly as a -0.60% decrease in the ISEW. As for the MLIC a decrease of -0.035 pp and -0.147% in the short- and long-term, respectively. While in the HIC there is a loss of significance in the short-term but an increase in the elasticity (1.233) in the long-term.

5. Discussion: food, the output approaches and the wealth of the countries

In this section the results presented above are discussed with more detail and accounting for the economic relationships inherent in the models. Considering that this topic is relatively new to the literature, specially the analysis of economic growth and sustainable development through food consumption, the explanations to the relationships observed must be seen as possible suggestions that follow directly from the findings. However, in some cases, these results should be further tested with other approaches for robust purposes. Thus, this work is contributing with possible leads for further research. Tables 8 and 9 present a resume of the effects across the models.

5.1. Economic growth promotes meat, while sustainable development slows it

The findings about economic growth and meat consumption discussed in this section are in accordance with the literature. *GDPpc* is observed to be positively related to meat consumption, for all groups, at least in the short- or in the long-run. This outcome is far from being a surprise, actually. As people have more money to spend they tend to consume more high-calorie and protein products such as meat and other livestock products. A trend is observed in direction to the “westernized” pattern evident in the developing world. This finding is not reassured at all, although people by having more to eat can satisfy their calorie and protein needs, other problems derive as the ones explored in section 2 (health and environmental issues). The sustainable approach that considers the environmental damages and social inequality promotes meat consumption as well, but at a smaller rate. This finding is important, in the way that if countries focus on the sustainable development, rather to the exhaustive burdensome economic growth seen in the late decades, meat consumption follows a slower and hence less damaging growth.

Table 8. Synthesis of results for meat consumption following both approaches

Models	**Growth Approach**			**Sustainable Approach**		
	I - MGHIC	II - MGUMIC	III - MGMLIC	IV - MIHIC	V - MIUMIC	VI - MIMLIC
Semi-elasticities						
CONS	(-)***	+	(-)***	+	-	(-)***
DGDP/DISEW	+	(+)**	(+)**	(+)***	(+)**	(+)***
DLPBCPC	(-)***	(-)**		(-)***	(-)**	
DLFSP	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***
DLXNI						
DLKOF			(-)***		+	
DLL	(+)*					
DLCPI	(-)***	(+)**			(+)***	
Elasticities						
LGDP/LISEW (-1)	(+)*	(+)***		+	(+)**	
LPBCPC (-1)	(-)***	-		(-)**	-	
LFSP (-1)	(+)***		(+)***	(+)***	(+)***	(+)***
LXNI (-1)						
LKOF (-1)				(+)**	+	(+)***
LL (-1)				(-)***		
LCPI (-1)	(-)***	(+)**		(-)***	(+)***	
ECT	(-)***	(-)***	(-)***	(-)***	(-)***	(-)***

Notes: GDP and ISEW are in per capita terms. ECT means error Correction Term. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

An aspect we have encountered in the models was the substitution effect of plant-based consumption on meat consumption. This finding, although not analysed in the literature, is the expected. Indeed, as people eat more plant-based products such as vegetables, legumes, cereals and fruits they tend to lessen the consumption of meat products. Vegetarians, for example, lean towards reducing meat consumption in favour of plant-based foods. However, this effect might not be present in the poorer regions. This could be explained by the fact that they do not have the conditions to favour one type of food over the other, since food (in)security is a persistent issue in these regions compared to the richer, developed ones. Therefore, by not observing any statistically significance it can be concluded that there is not relationship between the different types of food analysed in the poorer countries. When looking for protein, meat is seen as a reliable source, although some plant-based foods contribute to protein requirements as well, even so, with smaller quantities. This could also explain the high impact observed by the food security proxy, for all regions.

Globalization has a divergent effect per income level analysed, since developed countries can benefit from globalization, contrary to the poorer regions that may even be negatively affected by it. The reason could possibly relate to the relationship between globalization and inequality through the comparative advantages theory. Some studies suggest that the poorer countries do not have the sufficient characteristics to benefit from globalization, as they end up being exploited by the richer countries with better knowledge and negotiating power. This is evident in the real world, as the only advantage these countries have is their cheap labour force. Furthermore, the foreign direct investment (FDI) mainly explores this labour perspective, without accomplish any transference of technology or knowledge, as the core centres are kept in the developed world. With globalization, in this case, the MLIC are prejudicated probably in benefit of the developed regions (Bergh & Nilsson, 2010; Dreher, 2006; Dreher & Gaston, 2008). This could possibly explain the negative effect observed on meat consumption in the GDP model, for the short-term. As they do not absorb the benefits of globalization in their daily diets. Although, the effects invert in the long-term, observed in the ISEW model. Globalization could be damaging in the beginning of the process but with benefits associated with relative poor salaries, the citizens of these countries find a way to better satisfy their needs for food and further increase, once again with the income made at their disposal through FDI, for example.

The negative effect observed by employment in meat consumption, for the sustainable approach, can be viewed in terms of time availability. Often food consumption is associated with leisure, or more correctly, an activity not associated with the workplace. As people have jobs and a schedule to meet, they spend more time working and may even neglect the time to eat. Lunch time, for example, is often diminished over worktime. Indeed, people tend to spend less time eating, while working more. This could possibly highlight that people, by having a job and further a career, could be neglecting their diet, by eating less and poorer in favour of working more. This effect is only observed in the HIC. This is no surprise and could be mainly associated with the non-compliance with the working hours and being permanently vigilant and working in the complex roles performed. Also, only visible in the long-run possibly because this relationship is not affecting the daily basis of individuals, as opposed to the low significant (10%) semi-elasticity observed in the growth approach. Thus, having a positive effect at the start, but turning negative in the log-run.

Following the analysis, an impact that differs between the two developed groups is the consumer price index effect. In that it is seen a negative impact in the HIC in the long-run, contrary to the positive one present in the UMIC for both short and long-run. In the HIC it could be easily interpreted that as prices increase, in the long-run, consumption will decrease. However, in the UMIC, we could be facing the issue of inflation expectations, when analysing in the short-run. While people expect the prices to grow, they tend to consume more in the present, since their money will buy less in the future. In the case of the long-term none of these explanations seem to fit. This could possibly be related with the fact that in most of the UMIC, as Bulgaria, Romania and Turkey among the most significant, had some serious issues regarding inflation, with monthly rates on the order of the 200%, in the first half of the period analysed. Some even accounting CPI values below 50 in 2005, considering the base year of 2010. As the rate growth of inflation seems stabilized through the period analysed, this could be the main cause for the positive effect present in the long-term. As the inflation is stable at low rates, the impact, although positive, is very low (0.07 and 0.13 for both the growth and sustainable approaches, respectively).

5.2. Meat: the growth and sustainable approaches dilemma

By analysing the inverse relationship discussed above, we can understand the impact that food consumption has on economic growth and sustainable development. Furthermore, distinguishing between the growth approach associated with the conventional GDP and the sustainable approach related with the alternative ISEW. Some of the results above interpreted, deserve to be discussed in greater depth. For example, meat consumption is observed to be negatively affecting the developed and emerging regions while benefiting the poorer. Although, this effect changes when analysing for ISEW, in the most developed. From the observations, we can deduce that, first, meat consumption is analysed here as the sum of production plus imports minus exports. By considering this, the model may be capturing the negative impact of imports in the GDP, as many of the food in the developed world is imported from the poorer and cheaper countries. Thus, explaining both the negative and positive effects observed in the developed alongside the emerging economies and the poorer regions, respectively. However, a positive impact is seen in the most developed (HIC), at least for the short-term, when analysing through the sustainable approach. As ISEW captures the environmental costs associated with natural resources, it could be deduced that, by importing meat which is an intensive in resources product, from other countries, the environmental degradation is dislocated from the developed world to the exporting countries (Schmitz et al., 2012). Thus, explaining the positive effect. But how can the MLIC not be affected negatively in the ISEW model?

Two possible explanations can be deduced. One is that the quality of the data of these countries is very poor. As the data is processed by the specific countries, they lack in institutional and organizational levels. This could explain the not captured effect of natural resources depletion and thus the not statistically significant impact. The other explanation, as ISEW captures the issue of social inequality with the Gini index, meat could be associated with this convergence to more socially equal societies. As meat is of great value in the poorer countries, in terms of market product and thus a source of wealth. Both the lack of information on natural resources degradation and an increase in social equity promoted by the livestock sector could be behind the positive influence observed in the sustainable approach. Additionally, in the emerging UMIC, the relationship is negative for both the growth and sustainable approaches. It can be concluded that, considering countries like Brazil and China, the natural resources depletion and overall environmental degradation is high. As some of the countries have been through high growth levels, hence promoting high levels of production. But still the impact of exports could not be sufficient or even associated with meat, as their products are cheaper and of low value than some other quality food products possibly imported has they increase their quality standards.

Concerning the plant-based foods, as an alternative to meat and livestock products, show some interesting results are of particular interest. Once again, in the MLIC, plant-based consumption seems to follow a similar path to meat consumption. It promotes both growth and sustainable approaches. Although, in this case, observing for the UMIC, plant-based consumption seems to be promoting GDP, in the short-run, but decreasing ISEW, in the long-run. China, for example, is a major exporter of rice, known to be one of the most resource intensive foods within the plant-based group. An explanation could be that, exporters of plant-based foods, mainly cereals, benefit from exporting high quantities of these foods but are impaired in the environmental perspective. This can also be said for the HIC. Although, these richer countries seem to not even benefit economically from their environmental damage.

Considering the reduction of meat consumption, proposed in the literature, as far as 50%, following an increase in plant-based consumption to compensate for the nutrients loss. From an economic perspective, GDP would be severely affected where the effect of meat consumption is beneficial, mainly observed in the poorer export-dependent regions. However, this would be benefiting for the countries that would decrease its import quantities. The ISEW, capturing the environmental effects of food production, would also benefit from that change, as plant-based foods, while negatively affecting the sustainable approach, the rates are much lower. The substitution for organic sustainably-farmed plant-based foods is suggested as they are expected to damage less the environment, and thus the ISEW.

Regarding food security, proxied by the supply of protein, it is positively associated with GDP in the UMIC and MLIC. As it is expected, a country where its population is not concerned with having food to eat has the advantage of not having to spend attention and resources on a solution to the problem, therefore being socially stable. The health benefits associated with food being secured are tremendous. And people can go on their daily lives without concerning for their survival. Although, a negative influence is observed in the MLIC, while analysing the ISEW. The model could be capturing the environmental effects of protein-rich foods. Besides meat, other protein-rich products are tree-nuts such as nuts, peanuts, almonds, etc. Besides their nutritious levels there are very resource intensive as well. These products, as they are expensive are mainly consumed by the richer countries, although their production could be in fact dislocated to the poor countries with lower production costs and more resource abundant.

Table 9. Synthesis results of both approaches following meat consumption

Models	**Growth Approach**			**Sustainable Approach**		
	VII - GMHIC	VIII - GMUMIC	IX - GMMLIC	X - IMHIC	XI - IMUMIC	XII - IMMLIC
Semi-elasticities						
CONS	(+)***	-	(+)***	(-)***	+	(+)***
DLMCPC			(+)***	(+)***		(+)***
DLPBCPC	+	(+)***	(+)***			
DLFSP			(+)***		(+)***	
DLXNI			+	(-)**		
DLEUPC	(+)***	(+)***	(+)**		(+)**	
DLKOF	(+)**				(-)**	(-)***
DLGFCFPC	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***
DLL	(+)***	(+)**				(+)**
DLCPI		(-)***		(-)**		-
Elasticities						
LMCPC (-1)	(-)*	(-)***			(-)*	(+)***
LPBCPC (-1)	+			(-)***	(-)**	(+)***
LFSP (-1)		(+)***	(+)***	+	+	(-)***
LXNI (-1)			(+)***	(-)*	+	
LEUPC (-1)	(+)***	(+)***			(+)***	(-)*
LKOF (-1)	(+)***	(+)***		(+)**	-	(-)***
LGFCFPC (-1)	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***
LL (-1)	(-)**		(-)*	+	-	
LCPI (-1)			(+)***			(-)**
ECT	(-)***	(-)***	(-)***	(-)***	(-)***	(-)***

Notes: ECT means error Correction Term. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

In terms of food, the proxy for trade dependency could have two explanations. The first one is that it had an increase in exports quantities and therefore the ratio raises. On the other hand, an increase in imports makes it decrease in value. Countries with a value above 1 favour exports over imports, below 1, imports over exports. In agreement with the explanation presented for the meat consumption in the HIC. That meat consumption decreases GDP but is positively related with ISEW. By exporting more food, the value of the ISEW decreases, both on the short- as in the long-run, which could be a consequence of the depletion of natural resources. Furthermore, the MLIC are observed to be benefiting from exports, as it is expected, assuming the growth approach.

The globalisation index applied here shows that the phenomenon of globalization is benefiting the richer and damaging the poorer regions. This is also expected. Globalisation seems to be mainly negatively affecting the poorer regions when analysing through the sustainable approach. Considering that it incorporates some of the environmental costs associated with natural resources depletion, the poorer countries maybe be left with these burdensome costs as they do not have sufficient power to refuse some of the resource-intensive productions. This explanation is in accordance with the theory of the comparative advantages introduced earlier. As the main advantage of the poorer countries is their cheaper labour, and restricted by their low economic standards, these countries end up inevitably accepting the resource-intensive productions the developed world externalizes. While KOF is negatively associated with the sustainable approach in the UMIC, it has a change of effects when analysing through the growth approach.

The productive factors applied as control variables seem to behave in accordance with the literature. Energy use is observed to positively affect all income groups, analysing growth through both GDP and ISEW. Although, a negative influence is present in the MLIC, for the long-term. This could be associated with their lack in renewable energy approach. Since they mainly depend on fossil fuels, this has an impact on ISEW much notably than in GDP. Capital benefits all regions, as expected. Contrary to employment that has a peculiar negative influence over GDP, present in the long-run for both extreme sides of income level. This could be associated with an inefficiency in productivity. More employment should automatically mean more economic growth, but more employment could also mean less productivity. In the most developed countries the unemployment rates are up to the two digits, with the saturated markets more employees do not necessarily mean it will represent a benefit for the economy. However, the MLIC are still socially and institutionally troublesome. Disqualified, low quality workers could have a damaging impact on the economy. The CPI shows a positive impact on GDP, only in the poorer countries. This is expected, as high inflations in poor countries are known to promote growth (Ibarra & Trupkin, 2016).

6. Conclusion and final remarks

Motivated by the will to understand the interactions between food consumption, economic growth and sustainable development, this work can be divided in the following central questions: (1) confirm the positive effect of economic growth in meat consumption, as observed in the literature, (2) understand the relationships between food consumption, mainly meat consumption as it is highlighted in the literature, and both economic growth and sustainable development approaches, (3) analyze the results considering different income groups, and (4) evaluate the impact of the dietary shift proposed in the literature.

It is proposed in this study that meat consumption might be an important driver of economic growth and sustainable development, and to understand its inherent relationships is essential due to the externalities that meat consumption is associated and have been topic of major international agenda. In order to do so, the empirical analysis was conducted further understanding the short- and long-run effects through an ARDL approach. This study mainly emphasizes three different perspectives. (1) Both analysis inherent in the interactions are examined, i.e., the effect of meat consumption on economic growth and vice-versa. (2) The sample was divided in three major income level groups, namely high-income, upper middle-income and middle lower-income countries, in order to understand the different relationships between income groups. Lastly, (3) with the purpose of benefiting from a nourishing discussion a comparison is analysed between the economic growth approach, applying the GDP, and the sustainable development approach with the ISEW. By doing so, with the latter the environmental issues of intensive-resource productions not captured by GDP can be understood.

As expected, the growth approach promotes meat consumption, for all the analysed groups differing in impact level. Considering the sustainable approach, the effects on meat consumption are smaller, evidencing that following an economic growth that considers the environmental aspects of production leads to lower levels of meat consumption compared to the conventional GDP. Plant-based consumption is observed to impact meat consumption negatively, evidencing a substitution effect between these food products. Promoting more plant-based diets could lessen the impact associated with meat consumption. Although, this is not evident in the poorer regions.

Meat consumption affects economic growth at different levels, considering the income level analysed. Poorer regions are observed to benefit more than developed countries. As these show a negative impact. On the other hand, meat consumption seems to be negatively affecting the emerging economies when analysing economic growth through the ISEW. While the richer benefit in the latter. Therefore, meat consumption has divergent impacts when GDP and the ISEW are compared.

Considering the reduction of meat consumption, proposed in the literature, having some authors even suggesting a 50% decrease, the impact on economic growth could be severe. Although, such proposed decrease, besides benefiting the environmental, is captured by the ISEW in a positive way. Suggesting a decrease on economic growth, but benefiting the sustainable approach. This could also be an incentive for the decoupling from the conventional economic growth approach towards the sustainable development approach. Some authors calling it the *degrowth* approach (Lorek & Fuchs, 2013; Weiss & Cattaneo, 2017; Worldwatch Institute, 2012). Economic growth cannot grow infinitely without considering the externalities associated mainly with production, such as the environmental associated.

As the food sector is an essential component in the daily life of every citizen, its consequences should be further analysed. Meat consumption, and overall food consumption, has an impact on the planet and on the individuals. Its relationship with economic growth should be pursuit in order to understand the effects of the recent trend to a more "westernized" diet heavy on resource-intensive products like meat and livestock in emerging economies, contrary to the small reductions observed in some highly developed countries. Although, a plant-based consumption could be part of the solution, there are some risks associated, felt in the economy. For example, the lower impacts felt in the growth approach, contributing to lower rates of economic growth compared with meat consumption, however the impact on the sustainable approach is also less damaging. Furthermore, it is found that an economic growth sustained on high levels of resource-intensive consumption, although it promotes growth, it is observed to negatively impact the more sustainable approach. Overall, meat consumption introduces a dilemma. Whether to produce while not considering the environmental associated costs, or see fit a more sustainable approach, preserving the ecosystems but while reducing the rates of economic growth. In the future, growth will be put in question in favour of the need for sustainable concerns. Additional research is in need for a possible solution to the dilemma proposed and to further understand the relationships here discussed for the first time, specifically food consumption both in the growth and sustainable approaches, as this topic of food economics is very recent and with many questions left to be answered.

7. References

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Appendix

Table A.1. Variables definition, sources and models where applied

Variables	Definition	Source	Models
GDPPC	Gross domestic product per capita (constant 2010 US$)	World Development Indicators	I, II, III, VII, VIII, IX
ISEWPC	Index of sustainable economic welfare per capita	Own elaboration (WDI & SWII)	IV, V, VI, X, XI, XII
MCPC	Meat consumption per capita	FAO Food Balance Sheets	All
PBCPC	Plant-based consumption per capita	FAO FBS	All
FSP	Protein supply (kg/capita/day)	FAO	All
XNI	Exports divided by imports (food trade index)	FAO FBS	All
KOF	Globalization index (overall)	KOF Swiss Economic Institute	All
EUPC	Energy use (metric ton per capita)	WDI	VII, VIII, IX, X, XI, XII
GFCFPC	Gross fixed capital formation per capita (constant 2010 US$)	WDI	VII, VIII, IX, X, XI, XII
L	Employment	WDI	All
CPI	Consumer price index (2010 = 100)	WDI	All

Notes: ISEW components are specified in table 1. in the data section.

Table A.2. Models notation and specification

Notation	Specification	Notation	Specification
I - MGHIC	Meat consumption through GDP in HIC	VII - GMHIC	GDP through meat consumption in HIC
II - MGUMIC	Meat consumption through GDP in UMIC	VIII - GMUMIC	GDP through meat consumption in UMIC
III - MGMLIC	Meat consumption through GDP in MLIC	IX - GMMLIC	GDP through meat consumption in MLIC
IV - MIHIC	Meat consumption through ISEW in HIC	X - IMHIC	ISEW through meat consumption in HIC
V - MIUMIC	Meat consumption through ISEW in UMIC	XI - IMUMIC	ISEW through meat consumption in UMIC
VI - MIMLIC	Meat consumption through ISEW in MLIC	XII - IMMLIC	ISEW through meat consumption in MLIC

Table A.3. Descriptive statistics and cross-sectional dependence for HIC

	Descriptive Statistics					Cross-Sectional Dependence		
Variables	Obs.	Mean	Std. Dev.	Min.	Max.	CD-test	corr	abs(corr)
LGDPPC	665	10.1921	0.65043	8.54376	11.4251	93.98***	0.884	0.884
LISEWPC	665	9.42014	0.68353	7.24122	10.9359	62.9***	0.592	0.651
LMCPC	665	4.40319	0.25438	3.40836	4.90679	4.51***	0.042	0.448
LPBCPC	665	6.20225	0.20369	5.75363	6.73358	5.37***	0.05	0.386
LFSP	665	4.60199	0.13739	4.13613	4.92849	6.39***	0.06	0.392
LXNI	665	4.07497	1.65142	-0.6043	8.02876	1.51	0.014	0.381
LEUPC	665	8.17113	0.48492	6.63153	9.80798	19.23***	0.181	0.448
LKOF	665	4.35368	0.13302	3.72506	4.52596	76.13***	0.716	0.722
LGFCFPC	665	8.65714	0.6968	6.27788	9.96775	52.37***	0.493	0.606
LL	665	15.3625	1.44508	11.8907	18.8207	43.15***	0.406	0.609
LCPI	646	4.43097	0.21769	3.13752	4.84314	90.47***	0.876	0.955

Notes: The CD-test has N(0,1) distribution, under the null hypothesis of cross-section independence. Significance levels of 1% are denoted as ***.

Table A.4. Descriptive statistics and cross-sectional dependence for UMIC

	Descriptive Statistics					Cross-Sectional Dependence		
Variables	Obs.	Mean	Std. Dev.	Min.	Max.	CD-test	corr	abs(corr)
LGDPPC	437	8.6536	0.45312	7.11278	9.59479	61.76***	0.891	0.891
LISEWPC	437	8.09394	0.87088	6.14788	12.7263	22.21***	0.32	0.498
LMCPC	437	3.92014	0.37802	2.99655	4.69958	33.78***	0.487	0.65
LPBCPC	437	6.09025	0.33164	5.4485	7.16506	16.27***	0.235	0.525
LFSP	437	4.35006	0.19496	3.78169	4.70574	21.6***	0.312	0.523
LXNI	437	4.59182	1.81522	-2.6557	8.78703	-0.8	-0.012	0.402
LEUPC	437	7.2828	0.58269	6.06849	8.55005	29.62***	0.447	0.547
LKOF	437	4.03876	0.18826	3.2504	4.37096	39.98***	0.604	0.814
LGFCFPC	418	7.07397	0.52757	5.29907	8.3361	44.13***	0.666	0.676
LL	437	16.1938	1.51805	13.1714	20.4514	40.48***	0.611	0.769
LCPI	361	4.10764	0.72274	0.19926	5.36576	52.95***	0.929	0.929

Notes: The CD-test has N(0,1) distribution, under the null hypothesis of cross-section independence. Significance levels of 1% are denoted as ***.

Table A.5. Descriptive statistics and cross-sectional dependence for MLIC

	Descriptive Statistics					Cross-Sectional Dependence		
Variables	Obs.	Mean	Std. Dev.	Min.	Max.	CD-test	corr	abs(corr)
LGDPPC	380	7.1262	0.66393	5.62616	8.22428	57.14***	0.951	0.951
LISEWPC	380	6.66114	0.66894	5.19118	8.61416	17.75***	0.295	0.416
LMCPC	380	2.86259	0.73503	1.19918	4.37025	26.58***	0.442	0.634
LPBCPC	380	5.92892	0.32964	5.3812	6.68207	13.91***	0.231	0.569
LFSP	380	4.11536	0.18267	3.68638	4.64227	37.14***	0.618	0.626
LXNI	380	3.29041	1.90364	-1.4816	7.05774	0.58	0.011	0.352
LEUPC	323	6.32398	0.33173	5.36432	7.15758	23.02***	0.453	0.675
LKOF	380	3.81311	0.4098	0	4.16572	43.41***	0.854	0.854
LGFCFPC	379	5.50135	0.84661	-0.0495	7.26932	27.89***	0.549	0.583
LL	380	16.0348	1.58706	13.8794	19.9623	36.8***	0.724	0.947
LCPI	361	4.17518	0.44676	2.69565	4.96091	55.26***	0.97	0.97

Notes: The CD-test has N(0,1) distribution, under the null hypothesis of cross-section independence. Significance levels of 1% are denoted as ***.

Table A.6. Results of the 2nd generation panel unit root test CIPS

	At level			First differences		
Variables	HIC	UMIC	MLIC	HIC	UMIC	MLIC
GDPPC	4.289	1.89	-0.475	-4.249***	179.461***	-6.714***
ISEWPC	1.401	1.627	-1.811**	-7.246***	195.626***	-10.046***
MCPC	-2.954***	-2.358***	-2.008**	-16.668***	310.239***	-9.631***
PBCPC	-4.149***	-3.734***	-1.707**	-17.76***	489.72***	-9.752***
FSP	-3.439***	-5.221***	-3.523***	-16.27***	507.566***	-10.269***
XNI	-3.593***	-0.907	-3.988***	-17.432***	635.698***	-13.857***
EUPC	0.158	-1.497*	0.229	-12.766***	-10.577***	-8.62***
KOF	-0.951	-3.989***	-1.708**	-13.724***	-11.072***	-7.905***
GFCFPC	4.324	-0.857	0.186	-7.784***	-6.709***	-6.85***
L	4.17	-1.237	1.314	-6.189***	-7.525***	-9.016***
CPI	-6.277***	2.948	-0.626	-8.67***	-6.283***	-4.575***

Notes: The CIPS test assumes cross-section dependence, the null hypothesis tests if series are stationary.

Table A.7. Results for MC analysis with GDP, using FE Cluster

Variable	Growth Approach		
	I - MGHIC	II - MGUMIC	III - MGMLIC
DLGDPPC	0.111686	.20694281**	.61481858**
DLPBCPC	-.28732295***	-.1332404**	
DLFSP	1.6512577***	1.1364022***	.56886743***
DLXNI			
DLKOF			-.01394144***
DLL	.19909584*		
DLCPI	-.23588953***	.03821618**	
LMCPC (-1)	-.31840031***	-.17700334***	-.32029882***
LGDPPC (-1)	.06406756*	.09430894**	
LPBCPC (-1)	-.12952703***	-0.07959	
LFSP (-1)	.64196563***		.71250638***
LXNI (-1)			
LKOF (-1)			
LL (-1)			
LCPI (-1)	-.0726484***	0.012901	
CONS	-1.0804174***	0.290925	-2.020108***
Observations	612	342	360
R-squared	0.58573	0.413512	0.306697
F-test	49.230899***	19.39636***	32.92775***
Id p/group	34	19	20

Notes: The F-test is normally distributed N(0,1) and tests the null hypothesis of non-significance as a whole of the estimate variables. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

Table A.8. Results for MC analysis with ISEW, using FE Cluster

Variable		**Sustainable Approach**	
	IV - MIHIC	V - MIUMIC	VI - MIMLIC
DLISEWPC	.05197942***	.04300174**	.07682116***
DLPBCPC	-.26824212***	-.14289301**	
DLFSP	1.6505724***	1.2698515***	.67480636***
DLXNI			
DLKOF		0.13016	
DLL			
DLCPI		.0752162***	
LMCPC (-1)	-.3234561***	-.23544957***	-.34357598***
LISEWPC (-1)	.0199836*	.01359124**	
LPBCPC (-1)	-.08401514*	-0.11316	
LFSP (-1)	.60879595***	0.302108	.73942521***
LXNI (-1)			
LKOF (-1)	.10956755**	0.054919	.00981329***
LL (-1)	-.09837197**		
LCPI (-1)	-.04322202**	.02957732**	
CONS	0.176103	-0.17232	-2.0832036***
Observations	612	342	360
R-squared	0.589291	0.420309	0.256752
F-test	83.06613	27.8867	28.34716
Id p/group	34	19	20

Notes: The F-test is normally distributed N(0,1) and tests the null hypothesis of non-significance as a whole of the estimate variables. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

Table A.9. Results for GDP analysis, using DK-FE

Variables	Growth Approach		
	VII - GMHIC	VIII - GMUMIC	IX - GMMLIC
DLMCPC			.07113068***
DLPBCPC	0.020279	.07996857***	.11063895***
DLFSP			.14362202***
DLXNI			0.003373
DLEUPC	.11567683***	.1532725***	.07180224**
DLKOF	.06446164**		
DLGFCFPC	.19850145***	.1692263***	.10274556***
DLL	.26562181***	.13898085**	
DLCPI		-.03629212***	
LGDPPC (-1)	-.07912935***	-.12962144***	-.16793378***
LMCPC (-1)	-.00986597**	-.04809273***	
LPBCPC (-1)	0.00934		
LFSP (-1)		.10680409**	.08786628***
LXNI (-1)			.00571026***
LEUPC (-1)	.03392098**	.06069356***	
LKOF (-1)	.07643681***	.08361325***	
LGFCFPC (-1)	.02241923***	.02916364**	.05151791***
LL (-1)	-.02689542**		-.03071638**
LCPI (-1)			.04431456***
CONS	.41409567***	-0.12145	.88176731***
Observations	630	324	306
F-test	293.2366***	187.1733***	190.4587***
Id p/group	35	18	17

Notes: The F-test is normally distributed N(0,1) and tests the null hypothesis of non-significance as a whole of the estimate variables. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.

Table A.10. Results for ISEW analysis, using DK-FE

Variable	Sustainable Approach		
	X - IMHIC	XI - IMUMIC	XII - IMMLIC
DLMCPC	.09813813***		.47668071***
DLPBCPC			
DLFSP		.95760311***	
DLXNI	-.02497877**		
DLEUPC		.68292605**	
DLKOF		-.5947049**	-.03533103***
DLGFCFPC	.93331736***	.75844851***	.44275011***
DLL			.9533598**
DLCPI	-.73777017**		-0.75002
LISEWPC (-1)	-.18878645***	-.1814335***	-.30824661***
LMCPC (-1)		-.37898213*	.31769494***
LPBCPC (-1)	-.10108681**	-.34636062**	.25452019***
LFSP (-1)	.13286223*	0.655043	-.54687149***
LXNI (-1)	-.0191421**	0.020963	
LEUPC (-1)		.1561218***	-.22655273**
LKOF (-1)	.23272422***	-0.21093	-.04527155***
LGFCFPC (-1)	.19984616***	.26098096***	.31020326***
LL (-1)	.18666192**	-0.10347	
LCPI (-1)			-.08207951**
CONS	-3.7218551***	1.57637	2.114892***
Observations	612	396	306
F-test	484.1219***	157.8007***	70.82578***
Id p/group	34	22	17

Notes: The F-test is normally distributed N(0,1) and tests the null hypothesis of non-significance as a whole of the estimate variables. Significance for 1, 5 and 10% are denoted as ***, **, *, respectively.