Reducing Meat Consumption to Mitigate Climate Change and Promote Health: but Is It Good for the Economy?

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Abstract: With the growing population and increasing purchasing power, the sustainability of the food sector is questioned as environmental externalities derive from consumption, mainly the emission of greenhouse gases, which contribute to climate change. Academic literature has suggested strategies to efficiently manage food consumption, but one of the main implications is to reduce meat consumption. Such a reduction would mitigate climate change and other environmental externalities as well as reduce health-related problems. However, the livestock sector is also a relevant economic sector for the subsistence of any economy. Therefore, this reduction could threaten economic growth. Following a sample of 14 European high-income countries over more than four decades, the impact of food consumption on economic growth is assessed. Results suggest that both meat and plant-based consumption contribute positively to economic growth. Consequently, a reduction in meat consumption could have a negative impact on the economy. However, strategies to both reduce meat consumption and promote economic growth are discussed in line with the results, with plant-based foods as an efficient option to solve the dilemma. Furthermore, specific strategies for both the supply and the demand side, education on food production and consumption are recommended, particularly in primary schools. Children could learn about healthy and sustainable dietary habits that would not hamper economic growth, as these should be the seeds of future consumption habits.

Keywords Food economics; Climate change; Economic growth; Meat consumption; PCSE estimator

1 Introduction

1.1 Motivation

World population is expected to reach 9.7 billion by 2050, according to the United Nations [1]. Additionally, worldwide wealth, as income per capita, has been increasing for the past few decades. Combining rapid growth in both population and wealth is expected to lead to a shift in dietary habits, i.e., greater quantity, with meat taking a great share [2]. Following the latest report from the Food and Agriculture Organization (FAO),[1] although the number of undernourished people has been rising in the underdeveloped world of Africa and South

[1] Table 1 showing the nomenclature is provided at the end of the Introduction section.

America, in the developed world, overconsumption and obesity have also steadily increased at an accelerating pace over the past decade [3].

[Table 1]

Meat consumption has become a preferred option for many when choosing what to eat, mainly due to its increased affordability and accessibility and its nutritional value [4]. Despite the recent stagnation, in the last decade, high-income countries (HIC) have recorded the highest ever levels for consumption of meat and other livestock products, two to three times the world average [5]. Moreover, through benchmarking, emerging and developing economies can be seen to be shifting their dietary habits to the same animal-based and calorie-heavy diets common in HIC. World meat consumption has increased from 65 to 279 million tons in the last half century [6], and it is projected that global demand for livestock products will continue to increase by up to 70% over the next 30 years [7]. This trend is of urgent concern since the consumption of livestock products is directly and indirectly associated with a complex spectrum of negative externalities, from the environment to public health, and even threatens food security. It is also notable that plant-based products can generate other externalities through their use of chemicals such as fertilizers and pesticides. However, since a large amount of crops are used to feed livestock, a plant-based human diet would ultimately have a lowerimpact [8]. Authors such as Marlow et al. [9], Lacour et al. [10]and Poore and Nemecek [11] have compared different diets and foods and concluded that plant-based foods have a lower ecological footprint than livestock.

The relationship between livestock production, consumption and the environment has been studied in the literature from various perspectives: the depletion of natural resources, mainly land and water [12, 13]; environmental degradation, mostly in the form of deforestation and loss of biodiversity [14]; and the greenhouse gas (GHG) emissions associated with the sector [15, 16], which contribute to climate change and its potential consequences [17]. Moreover, livestock has also been associated with higher risks of non-communicable diseases (NCDs) [18], such as cardiovascular diseases [19], some cancers [20], type II diabetes [21], obesity and being overweight [22], as well as causing higher rates of resistance to antibiotics in humans [23]. Lastly, even the issue of food security has been raised, as the growing use of plant-based crops for meat production is controversial and considered by some authors inefficient [24].

While livestock products provide high-value food and other economic and social benefits, such as providing an important source of income through its consumption [25], plant-based products have several advantages, such as reduced emissions of GHG and less depletion of natural resources, and they contribute to a healthier life, with lower risks of NCDs. In the last report by the FAO [7] on livestock's contribution to global warming and the sector's potential to tackle the issue, the authors suggest many ways to reduce emissions from the sector. These range from enhancing the digestibility of feed to improving grazing and grassland management and as well as fostering energy savings at every step of the production chain.

While the need for reform in the sector's practices is recognized, the authors focus their attention on the supply side of the market, only suggesting measures that promote production efficiencies and leave the demand side undiscussed. In addition to better and more efficient practices on the supply side, policy intervention on the demand side also has significant potential for mitigating climate change [26, 27]. Complementing better supply-side practices with incentives for reducing some of the more environmentally burdensome foods, such as livestock, would be even more effective in reducing GHG emissions and the depletion of natural resources. Furthermore, it would also improve individual health through healthier dietary habits.

1.2 Reducing Meat Consumption Through the Demand Side

Basically, two main solutions have been proposed. The first one relies on technological change, a change in production efficiency, i.e., producing more and better with less. This approach has been considered by environmental economists. The second solution has been suggested by ecological economists and involves changing behaviours, specifically changing consumers' diets. This implies a reduction of the most environmentally burdensome foods, along with a more plant-based diet, which is known to be more eco-friendly (see Pearce [28]). For the latter, various targets and policies have been implemented in the form of economic, social and legal instruments with the aim of promoting more sustainable and healthy dietary habits [29–31].

At a first analysis, working with the demand side would bring quicker results since a reduction in certain burdensome food products would directly decrease their supply/production. Consequently, these same foods would have to be substituted by other less burdensome ones, such as plant-based foods, to compensate for the nutritional value lost. Moreover, the demand-side solution would also show quicker results than the supply-side solution, because technological progress takes time and resources. A reduction in the consumption of certain foods would imply a change in the habits of the consumers but would not require years of research and associated resources. However, would it be less expensive for the economy?

Westhoek et al. [32] propose a reduction of up to 50% in the consumption of livestock products, compensated with an increase in plant-based products. The authors show that this change in the behaviour of the consumers would achieve a reduction in GHG emitted by the sector of between 25 and 45%, as well as a reduced depletion of natural resources with a 23% per capita reduction in the use of cropland for food production (see also Frenette et al. [33]). Ultimately, the proposed change would contribute to the mitigation of climate change, encourage more sustainable management of natural resources and would bring improvements in water and air quality. Moreover, by consuming less livestock, it is also assumed that the results would be very positive in terms of health, reducing the rates of NCDs, obesity and overall healthcare costs for both the state and for individuals.

Along the same lines, McMichael et al. [34] defined a target of 90 g per day of meat consumption to achieve the objective of reducing GHG emissions to their 2005 levels, by 2050. High-consuming populations are expected to reduce their consumption, while low-consuming populations will increase theirs to an agreed, globally shared, level. Both high- and low-consuming populations are expected to benefit from the change, through gains in health and environmental sustainability as well as benefits in nutrition and income, respectively.

According to the Intergovernmental Panel on Climate Change (IPCC), this reduction should be pursued where consumption is higher [35]. Considering that HIC consume two to three times the world average [5], it is proposed that these high-consuming countries should drastically reduce their 794 Pais D.F. et al.levels of consumption by at least the 50% suggested above. The results would be beneficial for the environment and public health, but what about the economy? What would be the impact on an economy that has a livestock sector where millions of consumers invest in, when eating a steak or a hamburger they bought in the supermarket or the local restaurant?

1.3 Objective and Methods

The objective of the present paper is to understand the impact of a reduction in the consumption of livestock products on the economy of the highest-consuming countries. In view of the potential reduction suggested in the literature of up to 50%, this paper empirically addresses the relationship between food consumption and economic growth, using econometric techniques.

Although there has been empirical evidence on the effect of economic growth on food consumption [6, 36], literature on this relationship is scarce when discussing the reverse, i.e., the effect of food consumption on economic growth. Marques et al. [37] conducted a research on the dynamic effects of the interactions between food consumption and economic growth and found a negative impact from meat consumption for HIC. The authors suggest that, for the HIC assessed, this negative effect could be caused by imports, because an increase in consumption would increase imports and hence have a negative impact on economic growth. While the literature already highlights the benefits of restricting meat consumption and increasing plantbased food consumption, to achieve such a shift, it is crucial to understand its effect on the economy and be sure that such a fundamental change in consumers' deep-rooted dietary habits does not threaten the pursuit of economic growth.

The empirical analysis is focused on a set of high-income European countries, members of both the European Union (with the exception of Norway) and the OECD. The interest in studying European countries within the small but expanding academic framework of food economics stems from the fact that Europe is a major meat consumer but also a forerunner when discussing sustainability. The descriptive statistics section below shows that the average European citizen consumes a great amount of meat. Furthermore, according to a report from the World Wildlife Fund (WWF) [38], if every consumer in the world were to adopt the same consuming habits as the average European consumer, it would require three planets to satisfy consumption. The Earth has overshot its capacity to supply all its needs without generating negative feedback, and thus, a shift to a green economy is inevitable [39].

The empirical approach is conducted by using both panelcorrected standard errors (PCSE) and feasible generalized least squares (FGLS) estimators. They were applied to assess the relationship between food consumption and economic growth, more precisely the effect on GDP of a 50% decrease in meat consumption. Results revealed that a decrease in meat consumption could have a negative impact on economic growth; more precisely, a 50% decrease could result in a ≈ 4% reduction of the GDP. Another major finding was that environmental degradation, through its ecological footprint, is negatively associated with economic growth, which suggests that these countries could be paying a price for the pollution they create. Food policy implications are discussed for both the supply and the demand side, from farmers to consumers.

In addition to this introduction, the remaining sections are structured as follows: Section 2 displays the data and methods as well as a brief descriptive statistic. Section 3 interprets and discusses the empirical results, suggesting some strategies for both the supply and the demand sides. Section 4 highlights the main findings. Finally, Section 5 presents the conclusions.

2 Material and Methods

2.1 Data

The present analysis focuses on a panel dataset of 14 European Union countries, all of which are HIC and OECD members, namely, Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom. The timespan assessed was confined to the availability of data and runs from 1970 to 2013. Indeed, food variables were only covered up to 2013 at the time this paper was written. Other European HIC for which data was not available for the long period chosen were not included. Table 2 presents all the variables applied, including their definition, measurement unit and source.

[Table 2]

In order to assess economic growth, the common proxy was applied, i.e., gross domestic product (GDP). The GDP is in constant 2010US$. Meat consumption was analysed here in kilograms per capita, and it incorporates different types of meat, such as, bovine meat, mutton and goat meat, pig meat, offal, poultry and "other meat". Besides meat, plant-based consumption was also analysed to understand its impact on the economy as a possible substitute for a reduction in meat consumption. It includes four major plant-based food groups, specifically, cereals, fruits, legumes and vegetables. Consumption variables are obtained through the following equation:

$$\begin{aligned} consumption &= (production + \Delta\ stocks + imports - export) \\ &\quad - feed\ use - losses - seeding - other\ non\ food\ uses \end{aligned} \tag{1}$$

Following this method of calculation, it is assumed that all available food is actually consumed, since the losses parameter only considers the losses before the food leaves the shelf. This assumption tends to overestimate consumption, as household waste is not considered. The approximate share of household food waste is estimated to be around 30% of food produced for human consumption, equalling a total of 1.3 billion tons of food per year [40], but since there is no reliable information on specific food groups, waste was not considered in the analysis, following Vranken et al. [6] and Clonan et al. [36]. The FAO was the source for all data concerning food consumption.

Control variables were also applied to avoid bias by potentially omitted variables. An additional consumption variable was introduced for fish consumption, as fish could also substitute meat. Some of the common determinants of economic growth were used, namely, energy, capital and labour. A third control variable for the ecological footprint was also applied. This is used as a proxy for the environmental aspect of consumption, capturing negative externalities that may arise from it.

2.2 Descriptive Statistics

Following the established path, an initial analysis of the data was carried out. Focusing on meat consumption, Fig. 1 displays the average of all 14 countries, for all timespan, showing positive growth peaking at the end of the last century, specifically in 1998, with an average consumption of 91 kg per capita. The new millennium was characterized by a small fall in consumption followed by stagnation for the next few years, at close to 90 kg. Following a linear trend, it is possible to perceive positive overall growth.

[Fig 1]

To understand the specific trajectories, Fig. 2, composed of four graphs according to region, captures all the countries individually. In Northern Europe, Denmark contrasts with the rest of the countries in its region during the 1980s and 1990s. While Denmark displays a strong increase in the middle of the period, followed by a more recent decrease, Finland, Norway and Sweden show a steady increase throughout the period. In the end though, Denmark maintains in the first place as the highest-consuming country.

[Fig 2]

Similarly, in Central Europe, the Netherlands also contrasts with its neighbours, but this time for showing smaller values in the first half and in the later years of the period analysed. However, the increase is evident for all countries in the first half of the period, followed by a small reduction in the second half, and more recent stagnation in the kilograms consumed in the later years.

Regarding Western Europe, like the Netherlands, the UK shows the smallest consumption over the period. France and Ireland display similar consumption values, with a decrease in the beginning of the new century. In later years, consumption levels can be seen converging to similar levels.

Lastly, in Southern Europe, the countries present the highest increases, with all starting below the 60 kg per capita and the majority exceeding the 80 kg level by the end of the period. Stagnation is also evident in the beginning of the new century for all countries, although the increase is evident for most of the period. Furthermore, Table 3 summarizes the growth rates between countries by decade and the overall period analysed.

[Table 3]

As seen in Fig. 2, the highest growth rates are observed in the first half of the period, with southern European countries showing the larger percentages. Growth rates fall for the majority and turn negative for some countries in the second half of the period, with Denmark and Ireland showing the highest falls. Overall, only France presents a consumption of meat in

2013 lower than the one observed at the beginning of the period, while the highest rates are seen in Portugal and Spain, which have doubled their consumption during the period.

In spite of the recent decrease and stagnation, the levels of consumption for these European HIC are still very high. Considering the world target proposed earlier of 90 g cap/ day, Europe is still a long way above the desired level. Table 4 simplifies the challenge proposed, taking 2013 levels into account. Besides the 2013 levels, it shows the necessary reductions to achieve the 90 g. The values were converted to grams per capita per day for a better understanding and a direct comparison with the proposed target.

[Table 4]

It is clear that even a 50% decrease in meat consumption would not be sufficient to achieve the target proposed for any of the countries. The most meat consuming and therefore the farthest away from the target are Austria, France, Ireland, the Netherlands, Portugal and Spain which consume, on average, more than 250 g per capita per day, with Spain leading the rankings. Norway is observed to be the one closest to the target, with a difference of 55%, still more than half of that necessary. Moreover, according to the target proposed, red meat should be limited to no more than 50 g a day. In order to understand the weights of the different meats, Fig. 3 introduces the shares of the different types of meat in the overall consumption for the last year of the analysis (2013).

[Fig 3]

More than 65% of meat consumption comes from red meat. However, if red meat is considered separately, i.e., by type, it is evident that pig meat is the most consumed type, followed by poultry and only then bovine meat, with a few exceptions, which is positive because, in terms of sustainability, bovine meat is the most resource intensive compared with pig meat and more so than poultry. Nevertheless, pig meat alone, as red meat, surpasses the 50-g target, without even considering bovine. Half of the consumption in Austria, Germany and Spain comes from pig meat, while only the UK has preference for poultry. In contrast, Denmark is the only country choosing bovine above all other meats. Considering the importance given to reducing red meat consumption, conversely the consumption of white meat might increase and could lead to a deterioration in the quality of this type of meat. With more demand for chicken, producers might decrease quality to satisfy rising demand. Consumption of mutton and goat meat is only conspicuous in Greece and Norway, probably due to culture and tradition in the dietary habits of their consumers.

2.3 Methods

Given the nature of the sample, countries that (i) are directly and/or indirectly committed to the supranational guidance of the European Union and the OECD, (ii) belong to the HIC group, and also (iii) are committed to promoting advances in sustainability, it was expected that the variables might be correlated, and both spatial and temporal effects might be present. In order to pursue the objective proposed above, the estimation of the coefficients in the regression was determined through the use of econometric panel data techniques. Indeed, before the estimation of a model, a battery of diagnostic tests should be made to certify the robustness of the model and act as blueprints for the elaboration of the latter. All econometric procedures were performed using the statistics software STATA 14.

Following the path taken by Marques and Fuinhas [41], as a source of good procedures, (i) a prior inspection of the nature of the data was made (presented in section 2.2.); (ii) panel unit roots were assessed as well as complex error compositions such as the presence of heteroskedasticity, panel autocorrelation and contemporaneous correlation; (iii) depending on the results obtained, the most suitable estimator was chosen, such as the panel-corrected standard errors (PCSE) or the feasible generalized least squares (FGLS) estimators; and finally, (iv) the robustness of the results was assessed through comparison of the different estimators applied.

Both the PCSE and the FGLS estimators are well suited for estimation when in the presence of heteroskedasticity, autocorrelation and contemporaneous correlation among panels. The FGLS estimator follows the condition of $T \geq N$, which is verified in the present sample since the number of time periods ($T = 44$) is larger than the number of cross sections ($N = 15$), while the PCSE has no strict conditions regarding sample size [42, 43]. However, according to Beck and Katz [44], the FGLS could underestimate standard errors and variances and thus lead to overconfidence in the results. In other words, the assessment of the statistical significances could be biased. In other words, the assessment of the statistical significances could be biased, hence, the preference for the PCSE. Moreover, although the FGLS is known to work well in large samples (which is not the case here), the same is not clear for finite samples. Nevertheless, both estimators allow: (i) the error term εit to be correlated over countries; (ii) the use of the first order autoregressive process for εit over time; and (iii) εit to be heteroskedastic, according to the options specified when estimating the model. The model to be estimated is as follows:

$$Y_{it} = \alpha + \sum_{k=1}^{k} \beta_k F_{kit-1} + \sum_{j=1}^{j} \gamma_j C_{jit} + D_i + D_t + \varepsilon_{it} \quad (2)$$

where Yit is the dependent variable to be explained, which in this case corresponds to the GDP per capita and Fkit-l is a vector of the food explanatory variables (meat, fish and plant-based consumption), while Ckit includes the control variables applied (energy, capital, labour and ecological footprint) and εit is the error term. The subscript l in Fkit-l represents the number of lags of the variable. Di and Dt are country and time dummies, respectively. The β and γ symbols are the coefficients of the variables, while the country and year are represented by the subscripts i and t, respectively. The introduction of lagged consumption variables is to avoid potential problems of simultaneity bias (reverse causality) between the dependent variable and the explanatory food variables. In the following tables, the natural logarithms, denoted as L, were computed for all variables in order to facilitate the interpretation of the coefficients. First differences are denoted with a D.

Following the procedure established, a battery of specification tests was applied to assess the data characteristics. Firstly, the presence of cross-sectional dependence among the variables was assessed using the CD test (Stata xtcd command [45]). Table 5 shows the results as well as the descriptive statistics of the variables and reveals that cross-sectional dependence is globally present, which could be explained by the proximity of the countries, both economic, political and geographical.

[Table 5]

Furthermore, considering the presence of cross-sectional dependence, the second-generation panel unit root tests CIPS [46] were performed (Stata multipurt command). The results, displayed in Table 6, show that overall the variables reveal the presence of unit roots when considered in levels, both with and without trend. After calculating the first differences, the variables are observed to be stationary. After calculating the first differences, the variables are observed to be stationary, with the exception of three variables, specifically, LPBCPC, LFCPC and LEUPC which reject nonstationarity for 0 and 1 lags. To deal with this issue, the variables were lagged twice and introduced in the regression to account for past information, since the impact of these is only felt two periods later. The significance of the lagged variables further suggests their incorporation in the regression. Additionally, multicollinearity was assessed with the variance inflation factor (VIF). The results revealed that all VIF values are under 5, as well as a mean VIF of 2.74, suggesting that multicollinearity is not a concern.

[Table 6]

Following the analysis, the next step was to choose a suitable estimator. When comparing the fixed effects (FE) estimator and random effects (RE) estimator, the Hausman test corroborated the former by rejecting the null hypothesis of RE with a 1% significance level, as shown in Table 7. To further support the choice, the Breusch-Pagan Lagrange Multiplier (LM) test for RE was applied with the null hypothesis, H0 = variances across entities are zero, which meant that there is no panel effect and a pooled OLS would be preferred. Following the proposed line of thought about the proximity of the countries, the test suggested that the panel effect is present, rejecting the null hypothesis.

[Table 7]

Finally, the presence of heteroskedasticity, serial correlation and contemporaneous correlation among sections was assessed. The modified Wald statistic for groupwise heteroskedasticity in the residuals was computed, revealing that the data is heteroskedastic. For serial correlation, the Wooldridge test for autocorrelation in panel data was applied as well as the more recent bias-corrected Born and Breitung test (Stata xtqptest command [47]). The presence of serial correlation is verified with the rejection of both the null hypotheses of no first-order autocorrelation and no serial correlation, respectively. The parametric test procedure proposed by Pesaran and the semiparametric tests by Frees and Friedman were computed to assess contemporaneous correlation. The Breusch-Pagan LM test for contemporaneous correlation was also used. The rejection of all null hypotheses suggested that the residuals are not spatially independent, indicating the presence of contemporaneous correlation across sections. The results from the specification tests are displayed in Table 7.

The results of the specification tests suggested that the panel database is heteroskedastic, panel autocorrelated and contemporaneously correlated. Once again, due to the economic, political and geographical proximity of the countries, such a result was expected. With regard to the latter, it is important to use an estimator that is robust in the presence of these characteristics. As was mentioned, the PCSE estimator has been shown to be appropriate in handling such features, as long as the specifications are considered when estimating the model. These specifications are the options taken in the estimation, such as contemporaneously correlated standard errors with an AR(1) autocorrelation structure (option corr(ar1)) as well as a panel-specific AR(1) autocorrelation structure (option corr(psar1)). The FGLS estimator was also computed with the same specifications for comparison. Results are shown below.

3 Results

Following the assessment of the characteristics of the panel made in the previous section, two estimators were applied, and four models were estimated (two for each estimator). Models (I) and (II) were estimated using the PCSE with the specific option, while models (III) and (IV) follow the FGLS as displayed in Table 8, along with the results.

[Table 8]

Globally, results reveal strong consistency. Indeed, they lead to similar conclusions regardless of the model. Most of the variables proved to be consistently significant, independently of the model, both in terms of the different estimators and the different correlation structures specified. The Wald test is also significant at the highest level of significance (1%), which supports the consistency of the models. To further understand their consistency, a first analysis of the control variables is recommended. Indeed, both the classical control variables of capital and labour proved to positively affect economic growth, as was expected. In terms of energy, there is extensive literature on the effects of energy on economic growth (see Ozturk [48]; Tiba and Omri [49]), and the positive effect is clear for countries worldwide, including HIC [50, 51], the OECD [52] and Europe [53, 54]. Conversely, results show a negative effect for the ecological footprint.

Unlike the energy-growth nexus, literature on the effects of environmental degradation on economic growth is scarce. However, the inverse, the effect of economic growth on environmental degradation, is a hot topic of discussion. According to the principles of the well-known environmental Kuznets curve, environmental degradation increases with economic growth until a certain point (turning point), when it starts to decrease with increased income, following an inverted Ucurve [55]. Although new insights have been studied about other curve possibilities such as an N or inverted N-curve for specific regions and countries, the common U-curve persists.

Considering these facts, one can deduce that, for the present sample of HIC, environmental degradation has been reducing with increased economic growth, as these countries have evolved from the industrial to the services era. However, in the developing world, economic growth is associated with environmental degradation through resource-intensive industries, as was the case for HIC some decades ago. Therefore, one can postulate that environmental degradation might have a positive relationship in developing countries, since they tend to follow a “grow now, clean later” policy [55], while the effect may be negative for developed HIC. A possible explanation could be that the benefit from polluting more is lower than the cost of treating such pollution. With their concern for sustainability and climate change mitigation, HIC are committed to reducing GHG emissions, and with economic growth reaching levels of further small marginal growth, the ecological footprint here assessed might be capturing this effect. With the latter in mind, one can conclude that the consumption of more resources (ecological footprint) and environmental externalities (GHG emissions, climate change) might threaten economic growth for these European HIC and probably for other HIC.

By analysing the values of the coefficients, it can be observed that, in model (II) (the PCSE panel-specific), the control variables energy, capital and labour have a positive impact on economic growth of 0.25, 0.35 and 0.33%, respectively, given a 1% increase each. In the FGLS model (IV), the signs are the same, and impacts are similar (0.27, 0.26 and 0.25 respectively). Furthermore, the environmental degradation proxy, ecological footprint, has an impact of − 0.14 (II) and − 0.11% (IV) on economic growth given a 1% increase in its value.

For the food consumption variables, these also show statistically significant levels for the majority of the models, and all three show a positive impact on economic growth. According to models (II) and (IV), the highest impact comes from meat consumption (at a 1% significance level) with a 0.09 and 0.08% change in economic growth following a 1% increase in consumption, respectively. This is followed by plant-based consumption, with 0.08 and 0.06% changes, and lastly fish consumption (0.04 and 0.04%). These positive impacts are supported at the maximum of 5% significance levels.

3.1 Further Robustness Check

Despite the FGLS already being a suitable estimator to support the results from the PCSE, a further robustness check was undertaken. For this, a comparison was made between the PCSE, FGLS and the common panel data estimators of FE and RE, in line with the concerns highlighted by Reed and Ye [43]. The objective was to analyse the differences between the impacts and their significance levels. If the results from the common estimators were to be dissimilar from the specific PCSE, as was expected, then the PCSE should be robust, since the characteristics observed in the data were controlled for. The FE and RE estimators were expected to be biased since they were not controlled for, and showed different significance levels, although they maintained similar impact signals and coefficient values.

As can be seen in Table 9, a small number of explanatory variables appear not to be statistically significant. Although the Robust option for both the FE and RE estimators was applied to control for heteroskedasticity, the characteristics of contemporaneous correlation were not controlled, which will result in biased coefficients in terms of their significance levels, i.e., they appear not to be statistically significant when in fact they could be. Table 9 indicates that the FE and RE estimators, even with the Robust option, were not well suited to deal simultaneously with both serial and contemporaneous correlation. Furthermore, the robustness checks also suggested the need to apply alternative estimators such as the PCSE and the FGLS when computing this type of analysis in the presence of the data characteristics listed above.

Following the results of the FE and RE estimators could lead to incorrect conclusions and further erroneous implications.

[Table 9]

4 The Reduction of Meat Consumption

Remembering that the specific objective of this paper is to determine the impact of a 50% reduction in meat consumption on the economy, according to the results obtained from the analysed sample, it would be a ≈ 4% decrease. This effect is contrary to the one found by Marques et al. 2018 [37], which suggests that meat consumption has a negative effect on economic growth in HIC. This particular finding could suggest some heterogeneity in the sample. While the present research assesses 14 European countries which, due to their similar political and economic framework, are more homogeneous than the 33 worldwide HIC assessed in the latter, the time period is also different. This contrast between papers suggests the need for more research on this topic. Nevertheless, the negative effect of a reduction in meat consumption on the economy is to be expected, as the livestock sector is a major contributor to the economies and their subsistence, both in the domestic market and in the foreign market (through exports), and is in line with the recent report from the European Commission [56]. The authors of this report indicate that a reduction would severely affect the EU livestock sector, particularly the beef meat sector, and would impose complex challenges for farmers. However, these challenges should not be seen as obstacles for the sector and the overall economy.

4.1 Food Policy Implications

Considering that a reduction of meat consumption is necessary and should be pursued, the meat sector should adapt to the new market signals. Although the economy will be negatively affected, according to the results, the negative impact from the reduction of meat consumption could be controlled with an increase in plant-based consumption. In view of the fact that interventions and policies should be holistic and incorporate both the supply and demand sides of the market [57], the following are some potential policy strategies for the HIC under analysis here. These policies could provide an approach to facilitate the dietary shift while causing the minimum damage to the meat sector and the economy. Fig. 4 synthesizes the strategies addressed here.

[Fig 4]

Following de Boer et al. [58], the authors have here explored demand-side strategies to promote the adaptation of reduced meat consumption. The “less but better” strategy could not only address the demand side but also the supply side of the sector. The meat sector, including farmers, should specialize in high-quality meat products that are highly efficient in terms of resources (more sustainable) and with minimized health consequences (healthier). Following Röös et al. [59], limiting livestock to pasture could be an efficient option in terms of resources. Organic products should be prioritized when choosing what to produce. In this way, the sector would reduce its production, but through the enhanced value of high-quality products, overall profits would not be so drastically affected. Assuming a kind of "invisible hand" effect, it is expected that the market will develop on its own, although some farmers may have to withdraw from the supply chain, particularly those producing low-quality products.

However, sustainable products should be financially incentivized so they become available to low-income populations who would otherwise prefer other products for their low price. This is in line with Pigou's views on externalities [60]. If a product brings benefits to society (positive externalities), that product should be subsidized in order for the benefit to be internalized in the price. If a food is healthier and more sustainable, the externalities that come from it should be valued. The contrary is also true; products that produce negative externalities should be taxed. By doing both, subsidizing and taxing, the state gives consumers the information they need to act consciously and at a fair price.

The "less and more varied" strategy could also be addressed by the supply side. The previous authors have suggested smaller portions of meat accompanied with more vegetable protein, to promote diversity. According to Lusk and Norwood [61], vegetarianism could also contribute to a reduction in food expenditures. Indeed, suppliers could introduce "hybrid" products to implement such a strategy. For example, the Menus of Change initiative from the partnership of the Culinary Institute of America and Harvard T.H. Chan School of Public Health introduced The Blend [62], a "hybrid" burger made of beef and mushrooms. By substituting 30% of the beef with mushrooms in making the burger, a reduction in meat consumption would be easily achievable for the meat burger consumers. Simply put, by doing this, meat consumption could be reduced up to 30%, while plantbased consumption could increase in the same range (considering only the meat burger market).

Besides "hybrids", the meat industry could also invest in alternative meats made from plant-based products like tofu, seitan or even bean burgers [63] or other meat substitutes,

which have much smaller footprints according to Nidjam et al. [12], and in the high-technological cultured "lab" meat or, as some might say, "clean" meat [64]. Succinctly, in the face of twenty-first-century dietary challenges, the meat sector should adapt and diversify its "menu" in order to survive and to promote a more sustainable planet. However, considering only a reduction in the domestic market of developed countries, and an actual increase in developing countries, the overall production of meat may not be so highly affected, as it would probably be redirected to the developing countries, hence failing to achieve the desired effect. Therefore, international policy is also of great concern when addressing this issue.

Of course, these strategies would be simple if the demand side is willing to buy and consume these new and alternative food products. That is why, social campaigns should also be a part of the solution. Informative advertising campaigns to promote these products, through modern marketing techniques, should be given priority over normal meat products. International fast-food chains, by introducing "hybrid" or plant-based products, could be a good promoter of these products. However, priority should also be given to the healthier and more sustainable options, within the plant-based market. The choice of locally grown foods also contributes to a better environment, albeit with some exceptions [65]. Finally, possibly the most efficient way to promote the desired dietary shift is through education. In order to gain the "approval" of the demand side, consumers need to be educated on the subject of food consumption and its inherent positive and negative externalities.

Besides the usual social instruments such as disseminating information through campaigns and social movements, education is expected to achieve better results. Indeed, starting to educate children early on (primary education) food production and consumption would influence future consumers when forming their dietary habits. School canteens should also be reorganized to offer more alternative and sustainable menus. The FAO recently presented a good example of this strategy from Mexico, where pupils learnt how to plant and harvest and, in the end, eat what they had grown [66]. Besides narrowing the gap between humans and nature, children are given the tools they need to pursue sustainable habits, particularly if they know which foods are better and more sustainable to produce and consume. As children learn, a spillover is expected, which will positively "contaminate" their households with all the new knowledge they have learned, potentially changing the dietary habits of their households. In the same way that schools began to educate children on recycling some decades ago, schools should now start exploring how to educate future consumers on eating more healthily and sustainably [67, 68]. A simple starting point would be to grow school gardens. Even an indoor garden would be a great start for city schools with a shortage of space, where children could get their hands dirty and start to experience the world of food, which is just as important as the subjects of science and arts.

5 Conclusions

This paper focusses on a panel dataset of 14 European highincome countries, for the timespan 1970–2013, with the objective of understanding the impact on their economies of a 50% reduction in meat consumption. Considering the externalities associated with meat, from an environmental and public health viewpoints, a shift in dietary habits is desirable. In order to achieve this, and taking the data characteristics into account, the panel-corrected standard errors and the feasible generalized least squares estimators were applied to assess this relationship. In addition to meat consumption, plant-based consumption was also analysed, and both variables were found to have a positive impact on economic growth.

Since meat consumption has a positive impact on economic growth, for the sample of high-income countries analysed here, a decrease in its consumption would result in a reduction in gross domestic product; more precisely, a 50% decrease could result in a ≈ 4% reduction. However, considering the positive effect revealed of the consumption of plant-based products, an increase in the latter could minimize the negative impact of reducing meat consumption. There are a considerable number of strategies farmers should implement to adapt to recent and future shifts in food consumption. Through strategies as simple as changing the ingredients of some meat fast-food products, or investing in the quality of their products, as well as in new ones such as “clean” meat, the industry must adapt its “way of doing things” to a more sustainable one. On the demand side, probably the most efficient way to promote healthier and more sustainable dietary habits is through education. Food education should be a priority in primary schools, from school gardens to nutrition and environmental knowledge and other educational instruments. By doing this, we will sow the seeds for future harvests, since children’s role in this is twofold, as consumers of today and of the future.

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Tables

Table 1. Nomenclatures

CIPS	Cross-sectional augmented panel unit root test	NCDs	Non-communicable diseases
FE	Fixed effects	RE	Random effects
FGLS	Feasible generalized least squares	PCSE	Panel-corrected standard errors
GHG	Greenhouse gases	VIF	Variance inflation factor

Table 2. Variables, definitions and sources

Variables	Definition	Source
GDPPC	Gross domestic product per capita (2010US$)	World Development Indicators
MCPC	Meat consumption per capita (kg)	FAO Food Balance Sheets
PBCPC	Plant-based consumption per capita (kg)	FAO FBS
FCPC	Fish consumption per capita (kg)	FAO FBS
EUPC	Energy use per capita (metric ton)	WDI
KPC	Gross capital formation per capita (2010US$)	WDI
L	Employment (persons)	WDI
EFPC	Ecological Footprint per capita (gha)	National Footprint Accounts

Table 3. Growth rates by decade and overall period

	AUT	DNK	FIN	FRA	DEU	GRC	IRL
1980–1970	24.68%	40.95%	28.93%	17.30%	22.50%	31.21%	7.46%
1990–1980	8.55%	36.04%	5.40%	−2.91%	−0.67%	11.07%	12.23%
2000–1990	−7.52%	−25.43%	1.28%	0.47%	−12.87%	37.28%	4.27%
2010–2000	−5.05%	3.42%	15.37%	−10.02%	3.43%	−20.18%	−16.56%
2013–1970	**17.66%**	**53.15%**	**63.36%**	**−1.62%**	**8.94%**	**55.30%**	**7.61%**
	ITA	NLD	NOR	PRT	ESP	SWE	GBR
1980–1970	38.24%	20.26%	30.00%	39.50%	50.45%	18.50%	−1.89%
1990–1980	13.71%	14.52%	−4.11%	39.31%	32.64%	−7.84%	0.75%
2000–1990	3.53%	5.36%	21.37%	38.41%	19.84%	18.97%	6.40%
2010–2000	2.05%	−12.66%	8.35%	6.32%	−14.43%	13.97%	3.99%
2013–1970	**54.11%**	**43.06%**	**73.32%**	**172.11%**	**101.72%**	**49.68%**	**8.70%**

AUT, Austria; *DNK*, Denmark; *FIN*, Finland; *DEU*, Germany; *GRC*, Greece; *IRL*, Ireland; *ITA*, Italy; *NLD*, the Netherlands; *NOR*, Norway; *PRT*, Portugal; *ESP*, Spain; *SWE*, Sweden; *GBR*, the UK

The values in bold show the growth rates for the whole period analysed, instead of decades

Table 4. Meat consumption levels for 2013 and the necessary reductions (n.r.)

	AUT	DNK	FIN	FRA	DEU	GRC	IRL
2013	257	243	219	250	247	222	253
n.r.	167	153	129	160	157	132	163
	ITA	NLD	NOR	PRT	ESP	SWE	GBR
2013	241	252	198	259	273	229	230
n.r.	151	162	108	169	183	139	140

Table 5. Descriptive statistics and cross-sectional dependence

Variables	Descriptive statistics					Cross-sectional dependence
	Obs.	Mean	Std. dev.	Min.	Max.	CD test
LGDPPC	616	10.3327	0.4252	9.0791	11.4253	61.49***
LMCPC	616	4.3859	0.2325	3.5494	4.8320	28.09***
LPBCPC	616	6.1723	0.2544	5.6873	6.6975	8.89***
LFCPC	616	3.1242	0.5056	1.7380	4.1916	44.10***
LEUPC	616	8.1098	0.4271	6.4981	8.8728	30.63***
LKPC	616	8.8138	0.4646	7.1631	10.1582	48.95***
LEFPC	616	1.7467	0.2507	0.9768	2.4519	8.72***
LL	616	3.7879	0.1201	3.4229	4.0052	24.32***
DLGDPPC	602	0.0190	0.0260	− 0.0943	0.1059	33.29***
DLMCPC	602	0.0086	0.0474	− 0.3048	0.2	5.11***
DLPBCPC	602	0.0029	0.0485	− 0.1855	0.1636	9.44***
DLFCPC	602	0.0070	0.0759	− 0.3213	0.3724	2.89***
DLEUPC	602	0.0085	0.0441	− 0.2049	0.1927	24.11***
DLKPC	602	0.0118	0.0930	− 0.6414	0.2820	26.41***
DLEFPC	602	− 0.0223	0.4162	− 2.9081	2.1672	18.11***
DLL	602	0.0014	0.0172	− 0.0918	0.0543	21.67***

The CD test has $N(0,1)$ distribution and follows the null hypothesis of cross-sectional independence. Significance levels of 1% are denoted as ***

Table 6. Second-generation unit root tests

Variables	CIPS (Zt bar)					
	No trend			With trend		
Lags	0	1	2	0	1	2
LGDPPC	1.348	− 1.208	− 0.561	2.294	0.432	1.317
LMCPC	− 1.051	− 0.483	0.561	− 1.250	− 1.018	0.191
LPBCPC	− 3.971***	− 2.724***	− 1.111	− 5.126***	− 2.772***	− 0.604
LFCPC	− 5.105***	− 3.035***	− 3.164***	− 3.177***	− 0.648	− 0.617
LEUPC	− 5.056***	− 3.848***	− 2.607***	− 2.615***	− 1.574**	− 0.707
LKPC	− 0.110	− 2.015**	− 1.376*	0.093	− 1.448**	0.102
LEFPC	− 1.815**	− 0.019	1.158	− 1.506*	1.117	2.369
LL	2.995	− 1.404*	− 0.806	6.358	0.751	2.576
DLGDPPC	− 10.063***	− 7.749***	− 4.566***	−9.014***	− 7.177***	− 3.512***
DLMCPC	− 16.162***	− 12.005***	− 7.645***	− 15.395***	− 10.466***	− 5.733***
DLPBCPC	− 17.594***	− 15.499***	− 10.767***	− 17.348***	− 14.382***	− 9.312***
DLFCPC	− 17.452***	− 13.023***	− 8.350***	− 17.150***	− 11.889***	− 6.903***
DLEUPC	− 16.558***	− 10.935***	− 7.601***	− 16.378***	− 10.001***	− 6.181***
DLKPC	− 13.586***	− 10.518***	− 8.369***	− 12.233***	− 8.833***	− 6.684***
DLEFPC	− 17.179***	− 13.093***	− 10.871***	− 16.797***	− 12.073***	− 10.073***
DLL	− 5.948***	− 5.879***	− 3.740***	− 4.266***	− 4.311***	− 2.150**

The CIPS test is robust to cross-sectional dependence and the null hypothesis tests if series are non-stationary. Significance levels of 1, 5 and 10% are denoted as ***, ** and *, respectively

Table 7. Specification tests

Models	Pooled	Random	Fixed
Hausman test			144.90***
Breusch-Pagan LM test (RE)		1489.31***	
Modified Wald test			1889.09***
Wooldridge test	402.960***		
Bc Born and Breitung test			33.92***
Pesaran CD test		12.700***	9.766***
Frees CD test		1.519***	1.054***
Friedman CD test		134.140***	114.913***
Breusch-Pagan LM test (CD)			435.843***

The Hausman test has a χ2 distribution and tests H0 that unobservable individual effects are not correlated with the explanatory variables; the Breusch-Pagan LM test for RE tests H0, Var(v_i) = 0; the Modified Wald test has χ2 distribution and tests H0, no heteroscedasticity; the Wooldridge test is normally distributed $N(0,1)$ and tests H0, no serial correlation; the Born and Breitung test has a Q distribution and tests H0, no serial correlation; Pesaran CD test is a parametric testing procedure and follows a standard normal distribution, while Frees and Friedman CD tests are semi-parametric testing procedures and follow a Q and χ2 distribution, respectively; and the Breusch-Pagan LM test for contemporaneous correlation has a χ2 distribution and tests H0, no contemporaneous correlation. Significance levels of 1% are denoted as ***

Table 8. Results

Dependent variable *LGDPPC*				
	PCSE		FGLS	
Independent variables	(I) Corr(AR1)	(II) Corr(psAR1)	(III) Corr(AR1)	(IV) Corr(psAR1)
LMCPC (− 1)	0.0757**	0.0903***	0.0535***	0.0784***
LPBCPC (− 1)	0.0649*	0.0786**	0.0351**	0.0575***
LPBCPC (− 2)	0.0555	0.0716**	0.0057	0.0269*
LFCPC (− 1)	0.0287	0.0221	0.0309***	0.0299***
LFCPC (− 2)	0.0431**	0.0375**	0.0339***	0.0356***
LEUPC	0.2175***	0.2490***	0.2399***	0.2692***
LEUPC (− 2)	0.2509***	0.2504***	0.1774***	0.1964***
LKPCD	0.3521***	0.3475***	0.2677***	0.2606***
LEFPC	− 0.1429***	− 0.1816***	− 0.0750***	− 0.1074***
LL	0.3029***	0.3278***	0.1988***	0.2486***
CONS	1.2481**	0.7783	3.3052***	2.2448***
Obs.	588	588	588	588
R^2	0.9956	0.9992		
Wald ($\chi 2$)	1131.6817***	1353.3508***	2300.2983***	2953.8849***

The Wald test has $\chi 2$ distribution and tests H0: non-significance of all coefficients of the explanatory variables. ***, ** and * denote significance at 1, 5 and 10% levels, respectively

Table 9. Summary of results by model

Dependent variable *LGDPPC*						
	PCSE	FGLS	FE		RE	
Independent variables	(II)	(IV)	(V) Robust	(VII) AR(1)	(VI) Robust	(VIII) AR(1)
LMCPC (− 1)	+(***)	+(***)	+(NS)	+(NS)	+(NS)	+(***)
LPBCPC (− 1)	+(**)	+(***)	+(***)	-(NS)	+(***)	+(NS)
LPBCPC (− 2)	+(**)	+(*)	+(NS)	-(NS)	+(NS)	+(NS)
LFCPC (− 1)	+(NS)	+(***)	+(***)	-(NS)	+(***)	+(*)
LFCPC (− 2)	+(**)	+(***)	+(***)	+(NS)	+(**)	+(***)
LEUPC	+(***)	+(***)	+(NS)	+(***)	+(NS)	+(***)
LEUPC (− 2)	+(***)	+(***)	+(***)	+(**)	+(***)	+(***)
LKPCD	+(***)	+(***)	+(***)	+(***)	+(***)	+(***)
LEFPC	−(***)	−(***)	−(***)	−(NS)	−(***)	−(***)
LL	+(***)	+(***)	+(NS)	+(***)	+(NS)	+(***)
CONS	+(NS)	+(***)	+(NS)	+(***)	−(NS)	+(***)
Obs	588	588	588	574	588	588
R^2	0.9991		0.9261			
F test			***	***		
Wald ($\chi 2$)	***	***			***	***

The Wald test has $\chi 2$ distribution and tests H0: non-significance of all coefficients of the explanatory variables. ***, ** and * denote significance at 1, 5 and 10% levels, respectively

Figures

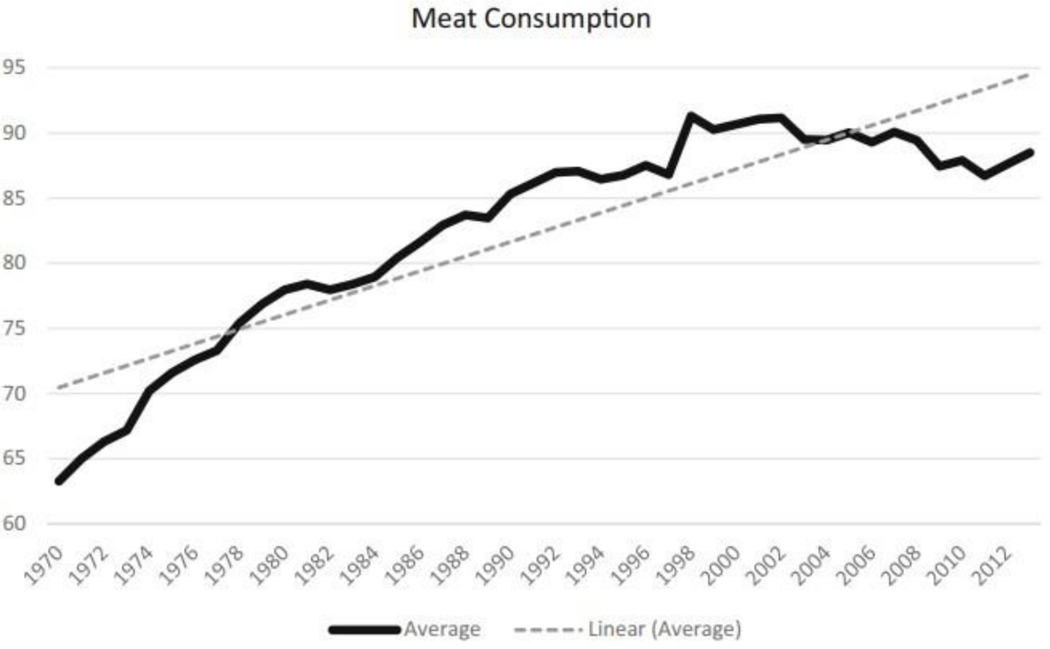

Figure 1. Average meat consumption and linear trend of all countries

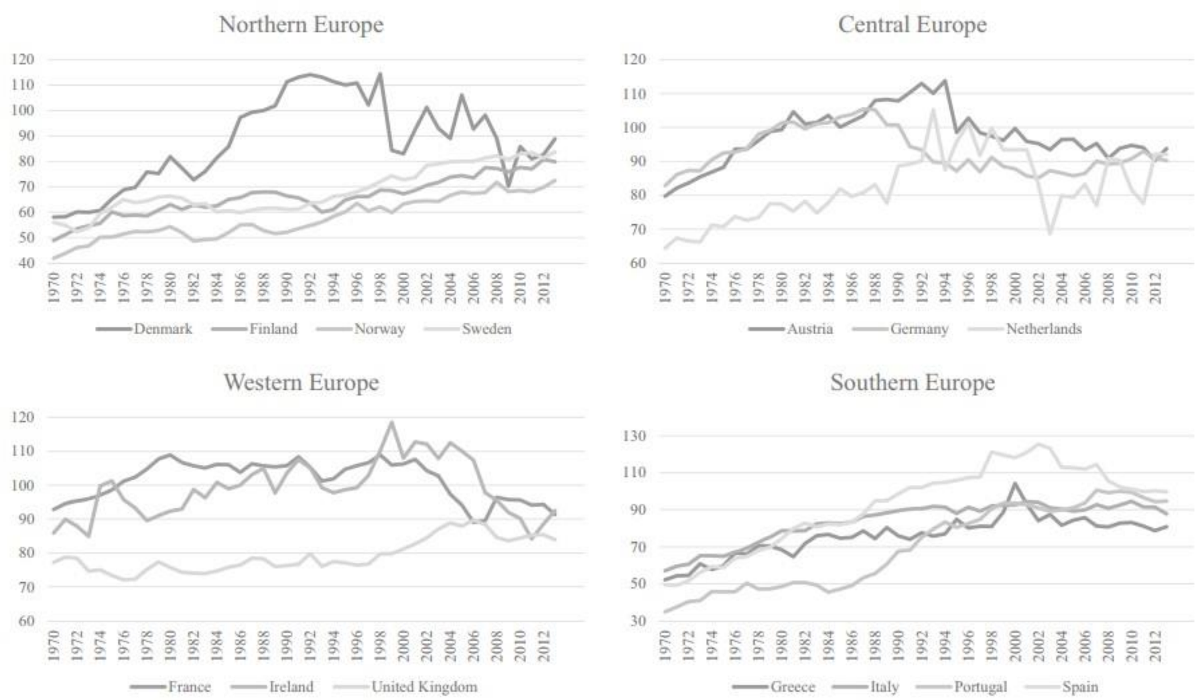

Figure 2. Meat consumption in Europe by region (1970–2013)

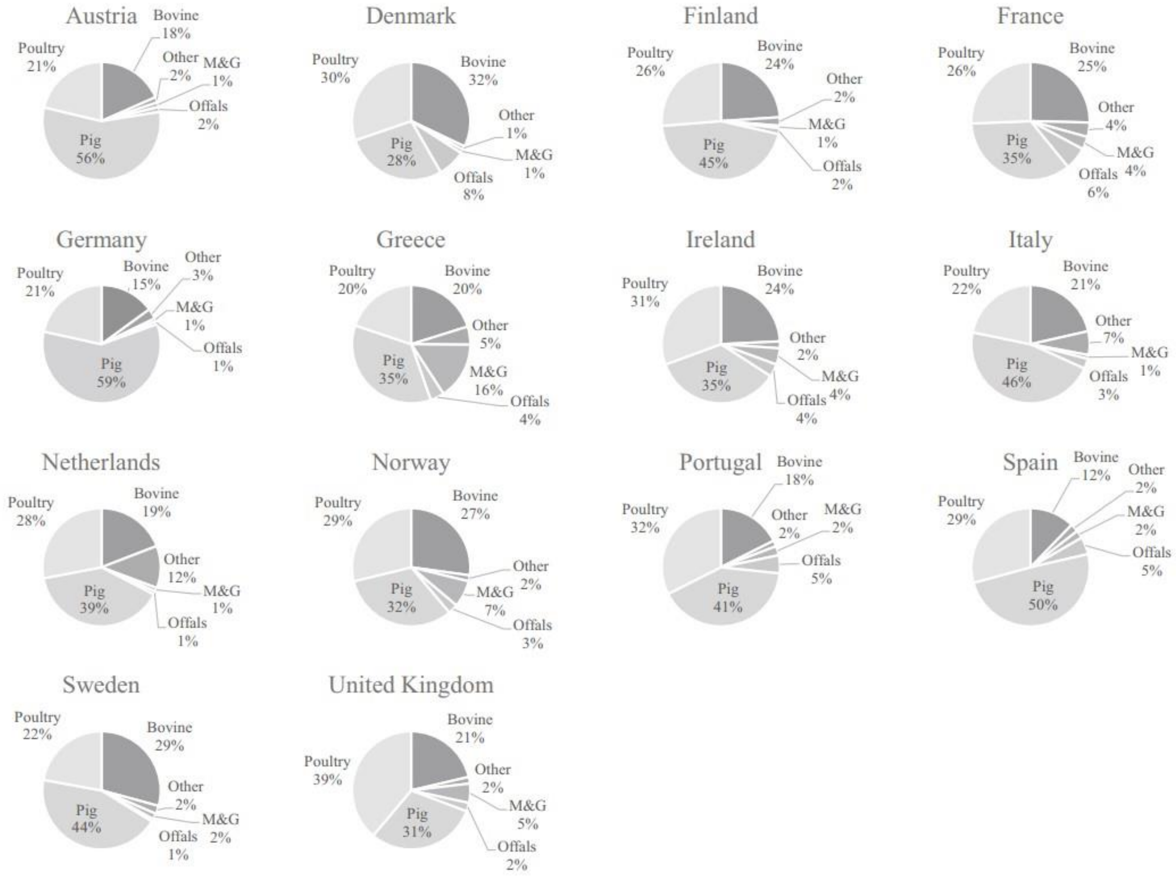

Figure 3. Meat consumption by type as % for 2013

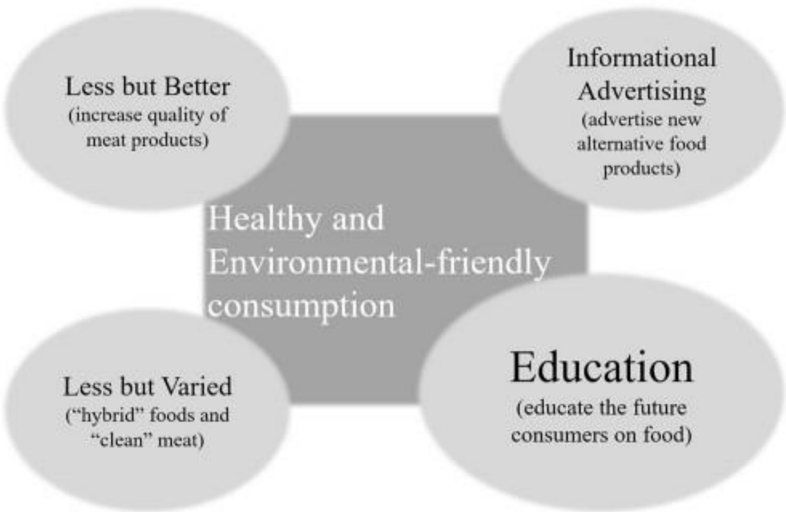

Figure 4. Diagram of strategies discussed