Simo-Kengne *et al. Agricultural and Food Economics* (2018) 6:12
https://doi.org/10.1186/s40100-018-0105-5

Agricultural and Food Economics

RESEARCH Open Access

Effect of marine protected areas and macroeconomic environment on meat consumption in SEAFO countries

Beatrice D. Simo-Kengne[1*], Johane Dikgang[1] and Sunita Prugsamatz Ofstad[2]

* Correspondence: bdsimo-kengne@uj.ac.za
[1]Public and Environmental Economics Research Centre (PEERC), School of Economics, University of Johannesburg, Johannesburg, South Africa
Full list of author information is available at the end of the article

Abstract

Livestock production and consumption of meat are significant contributors to today's most serious environmental problems and global warming. This paper investigates the role of marine reserves in shaping meat consumption pattern across member countries of the South East Atlantic Fisheries Organisation (SEAFO) for the period 1990 to 2009. Using a panel data including economic factors, life expectancy and environmental awareness, we find that meat consumption is positively associated with the presence of marine protected areas (MPAs). This suggests a possible increase in substitution of meat eating to seafood by SEAFO member countries due to aquatic resources conservation. Marine resource conservation policy is not a complementary strategy for sustainable livestock policy. This points out to some necessary policy improvements and actions to ameliorate the relationship between MPA and the negative environmental impacts of livestock. Furthermore, economic factors appear to have played a significant role in explaining meat consumption growth. Apart from price inflation, the most relevant factors that positively influence meat consumption appear to be GDP, exports and imports of agricultural products, and urbanisation. Beyond economic factors, negative health information associated with meat consumption appear to lead to a reduction in the consumed quantities of meat. There is evidence that meat-eating behaviour is not only related to macroeconomic development but also to environmental awareness.

Keywords: Consumption, Conservation, Environment, Macroeconomics, Meat

JEL classification: C32, O44, Q18

Background

Fish and seafood represent the primary source of protein for one billion poorest people on Earth (FAO 2010). With seafood, chicken and beef being equivalent in terms of protein supply (Yaktine et al. 2008); seafood is therefore a natural alternative to red meat. Moreover, a growing body of literature documents that consuming seafood may have important benefits for pre- and post-natal cognitive development and helps protect against heart disease and stroke. However, with the current debates on climate change and aquatic ecosystem threats, countries around the world have been facing a dilemma of how to respond to increasing demand in protein which reconciles economic, environmental and health benefits.

This is particularly critical for member countries of the South East Atlantic Fisheries Organisation (SEAFO) given their primary aim of safe-guarding the long-term conservation and sustainability of all marine resources in the South East Atlantic Ocean and protecting the environment and marine ecosystems. Maldonado and del Pilar Moreno-Sánchez (2014) argue that the expansion of marine protected areas (MPA) is a key prevailing management strategy to stop the degradation of coastal and marine ecosystems. However, the effectiveness of MPAs is affected not only by ecological factors but also by social ones. According to Leverington et al. (2010) only 24% of all protected areas globally are managed 'soundly'. These figures raise fundamental questions about the number of MPAs that are achieving their ecological targets or potential. Furthermore, many of the potential ecological benefits of MPAs are threatened by broader environmental conditions and extreme events (Keller et al. 2009).

Despite the popularity of MPA's as a resource management strategy, they are surprisingly few studies (see Darling 2014) that evaluate their socio-economic effects. As argued by Darling (2014), the recovery of fish biomass inside MPAs can spill over into nearby fished areas, resulting in increased fisheries yields and income. However, restricted fishing may also indirectly put pressure on alternative sources of animal protein such as meat. This implies that MPAs may potentially result in displacing fishing effort to other livelihoods such as livestock farming. Thus, understanding the effects of MPAs on food choice in general and, the demand for meat is crucial for environmental policy decision-making and problem solving.

Meat demand is complex, multi-faceted, and constantly evolving as new and important demand drivers develop over time in response to new information (Tonsor, Mintert and Schroeder 2010). Besides considerable changes observed in food habits, health information and environmental concerns have been recently advocated as important drivers of food demand. And this may alter the structure of empirical demand estimates. The purpose of this study is to examine the dynamics of SEAFO countries' meat consumption in relation to their economic performance under the fishing restriction. This is an attempt to shed light on the adaptive capacity of SEAFO countries to cope with protein demand.

Giving SEAFO's environmental awareness in term of long-term conservation of aquatic resources for the well-being of future generations, the question that arises is how sustainable the changes in meat consumption patterns across these countries are. Unlike previous studies that have looked at impacts of MPAs on human nutrition and health (see Gjertsen 2005; Aswani and Furusawa 2007), household income and economic vulnerability (see McClanahan 2010; Weigel et al. 2015), on household food security variables on meat consumption. This is an attempt to examine the social and economic effects of environmental conservation projects as they are manifested in MPAs.

There is a vast literature which considers various meat demand shifters, including urbanisation; health, price effects, livestock production and related information (Adhikari et al., 2006; Miljkovic and Mostad, 2005; Capps and Schmitz, 1991; Brown and Schrander, 1990); generic advertising (Park and Capps, 2002; Rickertsen, 1998; Brester and Schroeder, 1995) and structural changes (Davis, 1997; Moschini and Melke, 1989; Eales and Unnevehr, 1988). In recent years, substantial changes in potentially vital meat demand drivers have occurred (Tonsor, Mintert and Schroeder, 2010).

There are likely changes at two different ends of the spectrum in terms of nations' economic success. It would be expected that in countries with successful economies and rapid urbanisation, there will be increases in meat demands, dairy products and vegetable oils, which suggests more-intensive production and, for many countries, more imports (de Haen et al., 2003). Moreover, urbanisation is also linked with dietary shifts towards more processed and pre-prepared foods, partially in response to longer working hours and, for a proportion of the urban population, with reduced physical activity (de Haen et al., 2003; Popkin, 2001).

It also brings about major changes in demand for agricultural products both from increases in urban populations and demands (Satterthwaite et al., 2010). Many cities and towns owe their prosperity to their roles within the increased internationalisation system of production and distribution (Satterthwaite et al., 2010). According to Sassen (2006), there is therefore an obvious link between most of the world's largest cities and globalisation. Growing cross-border flows of raw materials, goods, information, income and capital, much of it managed by transnational corporations, have underpinned a network of "global cities" that are key sites for the management and servicing of the global economy.

A review of the past meat-price literature by Gallet (2010) concludes that meat is generally price inelastic. The median value for past studies on meat in general is – 0.710. Price elasticity becomes even more important in cases of a policy interest in moderating meat consumption through a tax. Cole and McCoskey (2013) state that price elasticities are key in assessing the financial effect on consumers and producers. For instance, a 2011 news story from online UK financial journal implied that growth in China's and India's demand for meat lead to a 25% rise in the price of turkey in the UK (Elliott, 2011).

Moreover, increased demand for convenience foods and growth in the food-away-from-home (FAFH) consumption is also influencing consumer eating choices (Byrne et al., 1996, Capps et al., 1985). In Norway, it was found that increases in the number of employed women with young children significantly affected total budget shares allocated to food and beverages as well as the food consumed away from home (Kalwij and Salverda, 2007). FAFH expenditure accounted for a larger proportion of food budgets for Canadian households with women employed outside the home (Horton and Campbell, 1991). U.S. demand for poultry was enhanced by increased female workforce participation (McGuirk et al., 1995).

Rising meat consumption also induces livestock production (Meissner et al. 2013), which is crucial for economic development and poverty reduction. The need for increased livestock production is pressing, due mainly to rapidly growing demand for animal products, and the key role livestock plays to the income and welfare of the rural poor (Upton, 2004). Moreover, agricultural markets have grown substantially with international trade; livestock accounting for over half of the value of the world's agricultural output and one third in developing countries. Therefore, increasing meat consumption come as a by-product of the economic growth through the development of meat industry and the related benefits in terms of job creation and government revenue expansion.

While the global meat industry provides food and a livelihood for billions of people, it should be noted that it also has significant environmental and public health consequences to the planet and its inhabitants (OECD 2015). One of the main challenges due to excessive consumption of meat is the production practises adopted by livestock producers to meet the ever-increasing demand. Unsustainable production practises lead to greenhouse gas (GHG) emissions, land degradation, impacts on ecosystem processes, biodiversity loss and unsustainable water requirement for meat production particularly in water scarce countries like South Africa.

Scholtz et al. (2013) argues that livestock production is the world's leading user of arable land resources. Moreover, a large body of the literature shows that health information has a significant impact on food demand. For instance,, Capps and Schmitz (1991), and Brown and Schrader (1990) used published medical research to build indices that proxy health information to which consumers have been exposed and found statistically significant effects from cholesterol information on U.S. meat and egg demand, respectively. Therefore, rising meat consumption also predicts a downward pressure on sustainable economic growth because of the associated health and environmental risks.

The rest of the paper is organised as follows. Section "Data and Methods" presents the data and methods. Section "Results and discussion" discusses the empirical findings and the paper ends with some concluding remarks.

Data and methods

The empirical investigation used panel data on meat consumption, GDP, food prices, health, environment, globalisation, urbanisation and convenience compiled from the FAOStat online statistical service, World Resources Institute to construct the convenience index constructed based on the processed livestock (see appendix).

Besides the EU, SEAFO covers six-member countries, namely, Angola, Japan, Namibia, Norway, South Africa and South Korea. Arguably, fish and seafood consumption are likely to be restricted in these countries due to their commitment to protect the oceanic environment. Unsurprisingly, although the consumption of fish is on the rise despite being uneven around the world, there seems to be shifts from seafood to meat eating. In addition, important disparities in socioeconomic factors exist among SEAFO countries which account for significant variation in the spatial distribution of meat production and consumption. The developed SEAFO countries (Japan, South Korea, Norway and EU) averaged an annual per capita meat consumption of 58.96 kg over the past twenty years. This figure is twice that of their developing counterpart (Angola, Namibia and South Africa) over the same period (see panel A of Table 1); hence confirming the literature that per capita meat consumption is higher in developed countries relative to developing countries. The average consumption for the latter in our sample is very close to the FAO (2009) average for developing countries of 30.9 kg. South Africa is an exception for Sub-Saharan Africa and identical to Japan and South Korea, and not far behind Norway in terms of meat consumption levels. Only the EU average is in-line with the FAO (2009) average for developed nations of around 82.1 kg (2005 estimate). The high average in meat consumption from our developed countries category is mainly driven by Japan and South Korea, which seem to be undergoing nutrition transition to "Westernised diets".

According to Gasparatos and Gadda (2009), the two regions in which this trend of "Westernised diet" is most widely manifested are South-East Asia and East Asia. Japan has experienced the most dramatic shifts in the dietary preferences of its citizens from seafood to meat eating. From the increasing trend in meat consumption (see Fig. 1) it is rational to conjecture that the creation of marine protected areas (MPA) might have

Table 1 SEAFO countries descriptive statistics

Panel A: macroeconomic characteristics of SEAFO countries, 1990–2009

Countries	Meat consumption (kg/person)	Real GDP ($ million)	Trade (ratio)	Urbanisation (% GDP)	Food prices (index)	MPA* (%)	Convenience (index)	Life expectancy (years)
Developing								
Angola	16.65	257,203	26.40	32.198	0.911	0.07	− 0.07	45
Namibia	28.53	6022.7	65.88	32.95	0.808	0.897	0.147	58
South Africa	43.29	220,586	22.24	56.75	0.996	2.977	0.19	57
Average Developing	29.49	161,270.57	38.17	40.63	0.905	1.314	0.089	53
Developed								
Japan	43.6	4,301,857	8.733	81.362	1.071	4.534	0.023	81
South Korea	43.55	703,547.8	14.93	79.13	1.057	3.56	− 0.25	76
Norway	59.85	266,480	9.95	75.505	0.969	1.68	0.16	79
EU	88.86	12,700,000	31.25	72.73	1.01	10.811	2.39	77
Average Developed	58.96	4,492,971.2	16.215	77.18	1.026	5.146	0.58	78

Panel B: pairwise correlations

	Meat consumption	Real GDP	Trade	Urbanisation	Food prices	MPA	Convenience	Life expectancy
Meat consumption	1							
Real GDP	0.77**	1						
Trade	− 0.27**	− 0.51**	1					
Urbanisation	0.79**	0.86**	− 0.70**	1				
Food prices	0.29**	0.36**	− 0.27**	0.40**	1			
MPA	0.69**	0.76**	− 0.02	0.53**	0.23**	1		
Convenience	0.17**	0.19**	0.11	0.04	− 0.07	0.39**	1	
Life expectancy	0.77**	0.74**	− 0.55**	0.87**	0.33**	0.48**	0.07	1

Panel A displays the socio-economic characteristics of SEAFO countries grouped into developed and developing countries with unit of measurement in parentheses, while panel B shows the cross-country descriptive statistics of variables in their logarithm forms apart from MPA and convenience. MPA is the weighted average of the percentage of territorial waters protected for conservation attributes

*, ** and ***level of significance at the 10%, 5% and 1% respectively

led significant reductions in seafood harvesting levels in SEAFO member countries, which might in turn have subsequently influenced dietary changes; resulting in increasing meat eating.

These high meat consumption countries differ in terms of economic growth, urbanisation, environmental awareness life expectancy and meat product convenience. Apart from South Africa, they are generally healthier (with the average life expectancy varying from 76 to 81) and characterised by a comparable level of urbanisation. Urbanisation fuels meat demand, and as can be seen from our sample, the more urbanised developed countries consuming more meat. In Norway for instance, urbanisation and rural-urban migration have been accelerating more that the rate of economic growth is much more

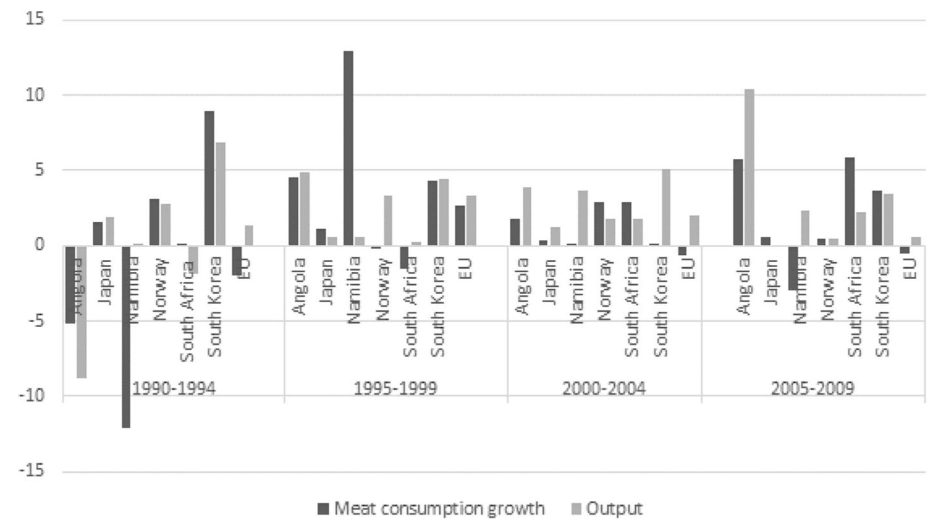

Fig. 1 Average growth rates of per capita meat consumption and per capita GDP across selected countries

stagnant now than it was ten years ago. Similar trend is observed in Japan and to a lesser extent in South Korea and Namibia due to their sluggish growth path and hence their lower purchasing power. Although the relative prices for food are close across our sample, the consumers in developed countries have more purchasing power.

The MPA measure indicates that most of the protected area is established in developed countries. The reasons for fewer establishments in developing countries include lack of capacity and infrastructure. A higher convenience value for developed countries reflects more diversified meat product portfolio. Trade refers to a ratio of exports and imports of agricultural products. A higher value as is the case with Namibia and the EU, suggests that they meet more of their domestic agricultural needs from national production.

For the empirical assessment, variables have been transformed in their logarithm forms. This eases the interpretation; allowing coefficients estimates to be interpreted in terms of elasticities. Pairwise correlation coefficients obtained from the transformed variables across SEAFO countries are presented in Table 1, panel B. Meat consumption appears to be strongly correlated with real GDP, urbanisation, MPA and life expectancy (with a correlation coefficient greater than 0.6). Similar pattern emerges from Fig. 1 where there seems to be a converging trend between per capita real GDP and meat consumption.

Since the per capita level of GDP provides a rough measure of the average living standards, improved living standards in developed countries might make it possible for consumers to purchase better quality foods including meat products. However, to draw efficient inference, such relation needs to be ascertained based on an econometric modelling.

The empirical analysis is based on panel time series modelling since the time dimension is dominant ($T = 20 > N = 7$). The major attraction of panel data rests on its ability to alleviate the issues of unobservable. In addition, it is usual to assume the absence of cross-section dependence in panels but Smith and Fuertes (2008) assert that such assumption appears restrictive for many applications in macroeconomics and finance. Spatial econometrics suggests a natural way to characterise dependence in terms of distance. However, for most economic problems there is no obvious distance measure (Baltagi, 2008).

Panel time series on the other hand, offers a variety of tools designed to deal with cross-sectional dependence; the choice of the method depending on purpose and characteristics of the data generating process. For this study, a contemporaneous correlation model is chosen which allows for autocorrelation within panels, cross-sectional correlation and/or heteroscedasticity across units. It is similar to a random effects model with disturbances comprising of three dimensions associated with time, space and both time and space, respectively (Podesta, 2002). This is estimated by the feasible generalised least squares (FGLS) which unlike a simple random model does not impose any restrictions on the error structure. More specifically, the model is given by:

$$Meat_{it} = a_i + \beta_i RGDP_{it} + \sum_{i=1}^{k} \lambda_i X_{it} + \varepsilon_{it} \quad i = 1, ..., N; \;\; t = 1, ..., T \tag{1}$$

where a_i is the country specific fixed effect, $Meat_{it}$ and $RGDP_{it}$ are the logarithm of per capita meat consumption and of real GDP, respectively; X_{it} is the vector of covariates including MPA, convenience and the logarithm of trade, urbanisation, food prices and life expectancy; and ε_{it}, is the error term.

Results and discussion

Table 2 reports the empirical results for three different specifications. Unlike the first model which assumes similar income and price elasticities for both developed and developing countries, the second and third models make use of the dummy variable (Dummy Developing is a binary variable which takes the value 1 when country i is developing and 0 otherwise) to differentiate income and price effects between the two groups of countries. Consistently with the literature, income elasticity appears to be positive and significant across the three models. However, the income effect is relatively higher in developed than developing countries with the elasticities of 0.05 and 0.03, respectively (full specification, model 3).

Table 2 Panel heteroskedastic with cross-sectional correlation, FGLS

Variables	Model 1	Model 2	Model 3
GDP	0.068***	0.066***	0.0501***
Price	0.056**	− 0.102	− 0.143**
Trade	0.162***	0.167***	0.236***
Life expectancy	−0.202**	− 0.224**	− 0.279**
Urbanisation	0.781***	0.805***	0.88***
MPA	0.0102***	0.012***	0.010***
Convenience	0.006**	0.0036	0.005
Price Dummy Developing		0.196**	0.258***
GDP Dummy Developing			− 0.0167***
Wald Test	Prob > χ^2 = 0.000	Prob > χ^2 = 0.000	Prob > χ^2 = 0.000

*Significance at 10% level
**Significance at 5% level
***Significance at 1% level

The price elasticity on the other hand is positive in the first model suggesting that meat is a Giffen good across SEAFO countries. Accounting for the level of development, we find that price elasticity in developed countries is negative and significant as expected from theoretical predictions. In developing countries, however, the price elasticity remains positive and significant. This is unsurprising as meat in developing countries is generally affordable either to households in relatively high-income categories with switching tendency to more meat eating because of improving diet or to subsistence farmers who have easy access to live stock products.

In line with the previous studies, meat consumption tends to increase with trade and urbanisation and to decrease with health information. More interestingly, the coefficient of the MPA is positive and significant, confirming an increase in substitution of meat eating to seafood by SEAFO member countries as MPA increases to help preserve aquatic resources. Every unit increase in the protected area is found to increase the per capita meat consumption by 1% across these countries. Consequently, with the greenhouse gas emission associated with rising meat production and consumption, the safeguard of the marine asset only might not be sustainable for SEAFO in achieving its goal to protect the environment and marine ecosystems. Beyond the protection of marine area, SEAFO management might consider restricting meat eating by promoting consumption of unthreatened seafood species by its member countries.

The global livestock sector is characterised by a dichotomy between developed and developing countries (World Bank, 2009). In developed countries, meat makes up a significant portion of the normal diet, contributing over 15% to daily energy intake, 40% to daily protein intake, and 20% to daily fat intake (Daniel et al. 2011). In the EU, meat consumption has stagnated recently, with notable increases in vegetarians and vegans (Global Agriculture, 2014).

Even through livestock production and merchandizing in developed countries account for 53% of agricultural GDP (World Bank, 2009); in developing countries on the other hand, the demand for meat continues to rise as production and consumption of meat increases with the improvement of economic capacity (Daniel et al. 2011). This pattern is expected to continue due to urban middle classes in emerging economies as they adapt to the "Western diet" (Global Agriculture, 2014) with important environmental consequences.

According to Linseisen et al. (2002), meat can be categorised into red meat (such as beef, lamb, veal and pork), white meat (including fish, chicken, game and turkey) and processed meat (including cured and smoked meats, ham, bacon, sausages, hamburgers, salami and tinned meat). Unlike white meat, the significant increases in red meat consumption is undesirable as it is accompanied by greenhouse gas emissions (Herrmann 2009), risk of cardiovascular diseases (Fraser 1999; Kelemen et al. 2005; Kontogianni et al. 2008) among others and risk of cancers (Wei et al. 2004; Robertson et al. 2005; Cross et al. 2007; Kimura et al. 2007; Taylor et al. 2007; Kabat et al. 2009).

Livestock farming, distribution, and consumption of meat has among the largest environmental impacts on scale which ranges from local to global. The industrial, high concentration of animal-feeding operation farming practices of raising animals solely for food in confined environments with lax restrictions on resultant pollutants are reasons for unsustainable resource use and significant air pollution and resultant climate change, water overuse and pollution, land degradation, arable soil erosion, fossil-fuel use, climate change, and biodiversity loss (Foley et al. 2011). Thus, livestock production is one of the major driving forces pushing the environment beyond its ecological carrying capacities. It is estimated by Cole and McCoskey (2013) that currently over ten billion acres of the terrestrial portion of the planet is used to raise animals for food.

Most importantly, the increases in meat consumption must be matched by rises in meat production, which accelerates the rate of deforestation and thereby contributes to soil erosion and desertification. Consequently, the industrial growth in industrial-scale, factory-farmed livestock particularly beef has contributed to a host of health and environmental problems and is patently unsustainable economically. Henceforth, diversifying the countries' nutrient sources and finding safe and environmental friendly protein supplies might contribute to the long term development and environmental sustainability have become one of the policy makers' main priorities.

Conclusion

While seafood is considered as a more environmentally-friendly alternative to red meat consumption, the major objective of the SEAFO is the conservation and management of straddling and high seas stocks in the South East Atlantic. Thus, increasing meat production and consumption could be considered as a solution to ensure the long-term conservation and sustainable use of the fishery resources in SEAFO's area of competence. However, with the negative impact of meat consumption on the environment and health which are not conducive to economic growth, a better understanding of what the trade-offs are in terms of balancing seafood as opposed to meat production and consumption is required to assess the environmental sustainability of the SEAFO member countries.

In this paper, the determinants of meat consumption are analysed for the period 1990–2009 using Panel estimation techniques. When heterogeneity is controlled for, empirical findings indicate that income growth, urbanisation, trade, change in diet and MPAs significantly affected meat consumption. Meat consumption tends to increase as economies develop and integrate; the improvement in economic growth facilitating imports and exports of agricultural products which in turn simulate the demand of meat and meat related product.

Similarly, significant increases in demand for meat is attributed to the fast progression of urbanisation and changing food consumption patterns by city dwellers to nutrient rich food such as meat. Moreover, an increase in MPAs is likely to induce further growth in meat eating; suggesting an increase substitution between seafood and meat eating because of conservation of marine reserves. These findings suggest that the conservation policy of aquatic resources alone might not be efficient for the environmental sustainability as the induced increase in meat consumption is associated with greenhouse gas emission, which is harmful for the environment.

Therefore, SEAFO management might want to adjust its long-term conservation strategy to achieve environmental sustainability. On one hand, further development of the livestock sector in ways that maximises on its positive effects while controlling the negative impacts could contribute to increasing levels of nutrition, improving agricultural productivity, improving the lives of the rural poor FAO (2010), and to fulfilling the Sustainable Development Goals (SDGs) for 2016–2030.

Furthermore, there is a need for countries to diversify the source of proteins; seafood being the primary alternative to meat consumption. In Western diets, fish consumption is lower than red meat consumption and this fact can influence on total diet quality (Alegria-Lertxundi et al., 2014). According to the UN Food and Agriculture Organisation, the period 1960 to 2003 saw a 420% and 200% rise in meat and seafood, respectively against a decline of only 15% in red meat consumption. Despite the significant increase in fish consumption, it is still not at the desired levels. For instance, an average fish production per capita in Asian countries is 50 kg and only 25 kg per annum for the European Union countries (Sayin et al., 2010; Koç et al., 2009; Akbay, 2005). The development of MPA as is the case in SEAFO countries may hinder attainment of desired seafood levels. It might therefore be efficient for SEAFO management to restrict the consumption of red meat by promoting consumption of unthreatened seafood species by its member countries.

Several global strategies for MPA expansion have been proposed to reduce overexploitation of fishing stock. However, the loss of habitat outside MPA's will continue to affect habitats and species, and MPAs may displace human activities into areas that might be even more important for species persistence. This implies that MPAs potentially conflict with other livelihood practices, with implications for livestock production; which is one of the largest drivers of habitat loss, as well as being among leading causes of climate change.

Appendix

Construction of the convenience index

As indicated in the main text, the convenience index is proposed to capture the meat demand due to the expansion of convenient food also known as processed food. Given the importance of processed livestock in producing convenient food, we construct an index from the available processed livestock products such as milk, cheese, and related items.

Let P be the vector of processed livestock products, P_1, P_2, ..., Pn and T be the time dimension associated with the sample period, $t = 1,\ldots\ldots\ldots T$. it is possible to construct N linear combinations.

$$C_1 = \mathbf{a}_1'\mathbf{P} = \mathbf{a}_1\mathbf{1}P_1 + \mathbf{a}_1\mathbf{2}P_2 + \cdots + \mathbf{a}_1\mathbf{N}P_\mathbf{N}$$

$$C_2 = \mathbf{a}_2'\mathbf{P} = \mathbf{a}_2\mathbf{1}P_1 + \mathbf{a}_2\mathbf{2}P_2 + \cdots + \mathbf{a}_2\mathbf{N}P_\mathbf{N} \vdots$$

$$C_\mathbf{p} = \mathbf{a}_\mathbf{p}'\mathbf{P} = \mathbf{a}_\mathbf{p}\mathbf{1}P_1 + \mathbf{a}_\mathbf{p}\mathbf{2}P_2 + \cdots + \mathbf{a}_\mathbf{N}\mathbf{N}P_N$$

So that

$$\mathbf{Var}(C_\mathbf{i}) = \mathbf{a}_\mathbf{i}'\boldsymbol{\Sigma}\mathbf{a}_\mathbf{i}, \mathbf{i} = \mathbf{1}, \ldots, \mathbf{N} \qquad \mathbf{Cov}(C_\mathbf{i}, \mathbf{C}_\mathbf{k}) = \mathbf{a}_\mathbf{i}'\boldsymbol{\Sigma}\mathbf{a}_\mathbf{k}, \mathbf{i}, \mathbf{k} = \mathbf{1}, \ldots, \mathbf{N}$$

The principal components are defined as those uncorrelated linear combinations $C_1, \ldots, C_p$ whose variances are as large as possible. For this study, we choose the first principal component which is the linear combination of maximum variance and is given by:

$$C_1 = \mathbf{e}_1'\mathbf{P} = \mathbf{e}_1\mathbf{1}'P_1 + \mathbf{e}_1\mathbf{2}'P_2 + \cdots + \mathbf{e}_1\mathbf{N}'\mathbf{P}_\mathbf{N}, \mathbf{i} = \mathbf{1}, \ldots, \mathbf{N}$$

with e the initial variable (P) is linked to the first component by the following relation:

$$\frac{\rho_C \mathbf{i}, \mathbf{P}_\mathbf{k} = \mathbf{e}_\mathbf{i}\mathbf{k}\sqrt{\lambda_\mathbf{i}}}{\sigma_\mathbf{k}\mathbf{k};}$$

Where **e** is the eigenvector associated to the covariance matrix of the random variable P.

C_1 is the convenience index which is therefore the linear combination of different processed livestock products which has the highest share in the total variance $\mathbf{Var}(C_\mathbf{i}) = \mathbf{a}_\mathbf{i}'\mathbf{\Sigma}\mathbf{a}_\mathbf{i}$.

This index is constructed separately for each of the selected countries as they have different numbers of processed products from livestock.

Funding

Funding from the Research Council of Norway and South Africa's National Research Foundation through the South Africa–Norway Research Cooperation programme (SANCOOP) is gratefully acknowledged. We also acknowledge funding from the South African Department of Higher Education and Training's (DHET) Research Development Grant.

Authors' contributions

All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details

[1]Public and Environmental Economics Research Centre (PEERC), School of Economics, University of Johannesburg, Johannesburg, South Africa. [2]Department of Psychology, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway.

Received: 2 June 2017 Accepted: 24 April 2018
Published online: 01 July 2018

References

Adhikari, B.K., S. Barrington, and J. Martinez. 2006. Predicted growth of world urban food waste and methane production. Waste Management & Research : The Journal of the International Solid Wastes and Public Cleansing Association, ISWA 24(5):421–433

Akbay, C. (2005). Econometric analysis of households' food consumption demand in Kahramanmaras, KSU Journal of Science and Engineering, 8(1):114–121

Alegria-Lertxundi I, Rocandio AM, Telletxea AS, Rincón ME, Arroyo-Izaga M (2014). Relationship between the ratio of fish to meat consumption and diet adequacy in university young women. Nutricion. Hospitalaria, 30(5):1135–1143

Aswani S, Furusawa T (2007) Do marine protected areas affect human nutrition and health? A comparison between villages in Roviana, Solomon Islands. Coast Manage 35:545–565

Baltagi, BH (2008). Econometrics. Fourth edition. Berlin and Heidelberg Germany: Springer-Verlag.

Brester, G, and Schroeder, T (1995). The Impacts of Brand and Generic Advertising on Meat Demand. American Journal of Agricultural Economics 77:969–79

Brown, DJ and Schrader, LF (1990). Cholesterol Information and Shell Egg Consumption. American Journal of Agricultural Economics72:548–555.

Byrne, PJ, Capps, OJ, and Saha, A (1996). Analysis of Food Away from Home Expenditure Patterns for U.S. Households. American Journal of Agricultural Economics 78(3):614–627

Capps, OJ, Tedford, JR and Havlicek, JJ 1985. Household Demand for Convenience and Nonconvenience Foods. American Journal of Agricultural Economics 67(4):862–869

Capps, O and Schmitz, J (1991). A recognition of health and nutrition factors in Food Demand Analysis. Western Journal of Agricultural Economics 16:21–35

Cole JR, McCoskey S (2013) Does global meat consumption follow an environmental Kuznets curve? Sustainability 9(2):26–36

Cross AJ, Leitzmann MF, Gail MH, Hollenbeck AR, Schatzkin A, Sinha R (2007) A prospective study of red and processed meat intake in relation to cancer risk. PLoS Med 4(12):1973

Daniel CR, Cross AJ, Koebnick C, Sinha R (2011) Trends in meat consumption in the United States. Public Health Nutr 14(4):575–583

Darling ES (2014) Assessing the effect of marine reserves on household food security in Kenyan coral reef fishing communities. PLoS One 9(11):e113614 https://doi.org/10.1371/journal.pone.0113614

Davis, GC (1997). The Logic of Testing Structural Change in Meat Demand: A Methodological Analysis and Appraisal. American Journal of Agricultural Economics 79:1186–1192

de Haen, H, Stamoulis, K, Shetty, P and Pingali, P (2003). The world food economy in the twentyfirst century: challenges for international cooperation. Development Policy Review 21 (5-6):683–696

Eales, J and Unnevehr, L (1988). Demand for beef and chicken products: Separability and structural change. American Journal of Agriculture Economics 70 (3):521–532

Elliott, KC (2011). Is a Little Pollution Good for You? Incorporating Societal Values in Environmental Research. New York: Oxford University Press

FAO, 2009: The State of Food and Agriculture 2009: Livestock in the balance, Rome

FAO (2010) The state of world fisheries and aquaculture. Food and Agriculture Organisation, United Nations, Rome

Foley J, Ramankutty N, Brauman K, Cassidy E, Gerber J, Johnston M, Mueller N, O'Connell C, Ray D, West P, Balzer C, Bennett E, Carpenter S, Hill J, Monfreda C, Polasky P, Rockstrom J, Sheehan J, Siebert S, Tilman D, Zaks D (2011) Solutions for a cultivated planet. Nature 478(7369):337–342

Fraser G (1999) Associations between diet and cancer, ischemic heart disease, and all-cause mortality in non-Hispanic white California seventh-day Adventists. Am J Clin Nutr 70:532S–538S

Gallet, CA (2010). Meat meets meta: a quantitative review of the price elasticity of meat, American Journal of Agricultural Economics 92, 258–272

Gasparators A, Gadda T (2009) Land use and cover change in Japan and Tokyo's appetite for meat. Sustain Sci 4(2):1–13

Gjertsen H (2005) Can habitat protection lead to improvements in human well-being? Evidence from marine protected areas in the Philippines. World Dev 33:199–217

Global Harvest Initiative. (2014) 2014 Global Agricultural Productivity Report: Measuring Global Agricultural Productivity. Washington, DC.

Herrmann M (2009) Food security and agricultural development in times of high commodity prices. Discussion Papers No. 196, United Nations Conference on Trade and Development

Horton, S, and Campbell, C. (1991). Wife's Employment, Food Expenditures, and Apparent Nutrient Intake: Evidence from Canada. American Journal of Agricultural Economics, 73:784–794

Kabat GC, Cross A, Park Y, Schatzkin A, Hollenbeck AR, Rohan TE et al (2009) Meat intake and meat preparation in relation to risk of postmenopausal breast cancer in the NIH-AARP diet and health study. Int J Cancer 124:2430–2435

Kalwij, A and Salverda, W 2007. The Effects of Changes in Household Demographics and Employment on Consumer Demand Patterns. Applied Economics 39:1447–1460.

Kelemen LE, Kushi LH, Jacobs DR, Cerhan JR (2005) Associations of dietary protein with disease and mortality in a prospective study of postmenopausal women. Am J Epidemiol 161:239–249

Keller B, Gleason D, McLeod E, Woodley C, Airamé S, Causey B (2009) Climate change, coral reef ecosystems, and management options for marine protected areas. Environ Manag 44:1069–1088

Koç, A A, Işık, S, Erdem, Ş and Beyaz, FB (2009), The Impact of the EU Accession on the Citrus Industry in Turkey, AKIB (Mediterranean Exporters' Union), in Turkish; http://www.akib.org.tr/akib

Kimura Y, Kono S, Toyomura K, Nagano J, Mizoue T, Moore MA et al (2007) Meat, fish and fat intake in relation to subsite-specific risk of colorectal cancer: the Fukoka colorectal Cancer study. Cancer Sci 98:590–597

Leverington F et al (2010) Management effectiveness evaluation in protected areas - a global study, 2nd edn. University of Queensland, Brisbane

Linseisen J, Kesse E, Slimani N, Bueno-de Mesquito HB, Ocke MC, Skeie G et al (2002) Meat consumption in the European prospective investigation into Cancer and nutrition (EPIC) cohorts: results from 24-hour dietary recalls. Public Health Nutr 5(6B):1243–1258

Maldonado JH, del Pilar Moreno-Sánchez R (2014) Estimating the adaptive capacity of local communities at marine protected areas in Latin America: a practical approach. Ecol Soc 19(1):16

McClanahan TR (2010) Effects of fisheries closures and gear restrictions on fishing income in a Kenyan coral reef. Conserv Biol 24:1519–1528

McGuirk, A, Driscoll, P., Alwang, J. and Huang, H. 1995. System Misspecification Testing and Structural Change in the Demand for Meats. Journal of Agricultural and Resource Economics 20:1–21

Miljkovic, D and Mostad, D (2005). Impacts of Changes in Dietary Preferences on U.S. Retail Demand for Beef: Health Concerns and the Role of Media. Journal of Agribuiness 23:183–198

Meissner HH, Scholtz MM, Palmer AR (2013) Sustainability of the south African livestock sector towards 2050. Part 1: worth and impact of the sector. S Afr J Anim Sci 43(3):282–297

Moschini, G and Mielke, KD (1989). Modeling the Pattern of Structural Change in U.S. Meat Demand. American Journal of Agricultural Economics 71:253–261

Park, J and Capps, OJ (2002). Impacts of Advertising, Attitudes, Lifestyles and Health on the Demand for U.S. Pork: A Micro-level Analysis. Journal of Agricultural and Applied Economics, 34 (1):1–15

Podesta, F (2002). Recent Developments in Quantitative Comparative Methodology: The Case of Pooled Time Series Cross-section Analysis. Discussion papers soc 3–02

Popkin, BM (2002). The Shift in Stages of the Nutrition Transition in the Developing World Differs from Past Experiences. Malaysian Journal of Nutrition 6(1):109–124

OECD (2015) Meat consumption. Indicator. https://doi.org/10.1787/fa290fd0-en

Rickertsen, K (1998) The Effects of Advertising in an Inverse Demand System: Norwegian Vegetables Revisited. European Review of Agricultural Economics 25:129–140

Robertson DJ, Sandler RS, Haile R, Tostesan TD, Greenberg ER, Grou M et al (2005) Fat, fibre, meat and the risk of colorectal adenomas. Am J Gastroenterol 100(12):2789–2795

Sassen, S. (2006). Deciphering the global: Its spaces, scales and subjects. New York, NY: Routledge.

Sayin, C, Emre, Y, Mencet, MN, Karaman, S and Tascioglu, Y (2010). Analysis of factors affecting fish purchasing decisions of the household: Antalya district case. Journal of Animal and Veterinary Advances. 9(12):1689–1695.
Satterthwaite, D, McGranahan, G and Tacoli, C (2010). Urbanization and its implications for food and farming. Philosophical Transactions of the Royal British Society 365, 2809–2820.
Scholtz MM, van Ryssen JBJ, Meissner HH, Laker MC (2013) A south African perspective on livestock production in relation to greenhouse gases and water usage. S Afr J Anim Sci 43(3):247–254
Smith, RP and Fuertes, AM (2008). Panel Time-series. cemap course. University of London.
Taylor EF, Burley VJ, Greenwood DC, Cade JE (2007) Meat consumption and risk of breast cancer in the UK Women's cohort study. Br J Cancer 96:1139–1146
Tonsor, GT, Mintert, J and Schroeder, T (2009). U.S. Beef Demand Drivers and Enhancement Opportunities. Kansas State University, MF-2893. Available at: http://www.agmanager.info/livestock/marketing/bulletins_2/industry/demand/Beef_Demand_Drivers_June_2009.pdf
Upton M, 2004. The role of livestock in economic development and poverty reduction. PPLPI Working Paper No. 10, FAO, Rome. World Bank, 2014. Tanzania at a glance. World Bank, Washington DC.
Wei EK, Giovannucci E, Wu K, Rosner B, Fuchs CS, Willett WC et al (2004) Comparison of risk factors for colon and rectal cancer. Int J Cancer 108:433–442
Weigel J-Y, Morand P, Mawongwai T, Noël J-F, Tokrishna R (2015) Assessing economic effects of a marine protected area on fishing households. A Thai case study. Fisheries Res 161:64–76
World Bank (2009). Minding the stock: bringing public policy to bear on livestock sector development.Washington, DC: Report no. 44010-GLB
Yaktine AL, Nesheim MC, James CA (2008) Nutrient and contaminant tradeoffs: exchanging meat, poultry or seafood for dietary protein. Nutr Rev 66(3):113–122