Seafood and climate change

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Abstract

Climate change is impacting marine and fresh water environments making food security a major concern due to the uncertainty of the quantity and quality of food that can be produced. Invariably this also has economic implications for food prices, industries' profitability and jobs. While there is value in considering wild caught fish and aquaculture as two distinct and separate sectors, in reality they are connected via the globalised markets and assessing economic impact needs to be considered along the whole of their supply chains. This paper employs two different economic models, a fishmeal and fish oil (FMFO) model and an input-output (IO) model, at two different spatial scales and under four climate-socio-economic climate change scenarios to capture the far-reaching economic implications of a changing natural environment. It aims to show how the wider economic implications can be assessed to provide insight that can be used for adaptive and cooperative policies to minimise negative economic impacts.

Keywords: Aquaculture, fisheries, seafood security, economic impact.

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1. Introduction

Food security is one of the major concerns under climate change due to the uncertainty of the quantity and quality of food that can be produced under ‘increasing temperature, changing precipitation patterns, and greater frequency of some extreme events.’ (Mbow et al. 2019:439). While a large proportion of research is focused on land-based food production (see for example Aryal et al 2019, Sofi et al 2019, Osei-Amponsah et al 2019), a growing research effort is being made in the marine and fresh water environments from where our seafood is sourced.

Changes in the temperature of the water will shift cold water fisheries further north (Rose 2005, Cheung et al. 2009) making them less accessible to the fishing sector and therefore more costly (Lam et al. 2011). It might, however, also bring opportunity to fish species which are not normally found in colder waters (Chen et al 2011). The aquaculture sector could also be affected due to increased damage to cages from extreme events, increased disease and the need to relocate farms. Even inland aquaculture farms could be impacted due to the need to keep the tanks cooler, competing products and variability of subsidies (Kreiss et al 2020).

While there is value in considering wild caught fish and aquaculture as two distinct and separate sectors, in reality they are connected via the globalised markets. The small pelagic fish (i.e. anchovies, sardines, capelin) captured in the waters of Peru and Chile are the key ingredient in the production of fishmeal and fish oil used as feedstock in the aquaculture farms of Europe. Decreasing catch of the Peruvian anchovetta due to climate change would lead to a decline in fishmeal and fish oil production and subsequently increased costs in aquaculture feeds which would negatively impact the profits of aquaculture farms. Economic impact is not confined to the fisheries and aquaculture industries. It extends along the whole of their supply chains impacting maintenance and repair, energy, transport and retail industries (Fernandes et al 2016).

The aim of this working paper is to quantify these wider economic impacts using two economic models which vary on spatial scale and economic detail. The first model is a global bioeconomic fishmeal and fish oil (FMFO) model that will be used to estimate the prices of fishmeal and fish oil used as aquaculture feed. The second model is an input-output (IO) model used to quantify the impacts of changes in the production of industries along their supply chains (i.e. direct and indirect impacts). The models are run under four climate-socio-economic scenarios to provide insight that could be used to create adaptive policies to minimise economic loss.

2. Methods and data

2.1 Fishmeal and fish oil (FMFO) model

Fishmeal and fish oil (FMFO) are used as feed-ingredients in the aquaculture sector to ensure farmed carnivorous fish, e.g. salmon and trout, have a nutritional, healthy diet (Huntington et al 2009). Various sources of FMFO exist including the small pelagic species: anchovies, herring, capelin, sardines and mackerel. The Fishmeal and Fish oil (FMFO) model estimates potential global fishmeal and fish oil prices under assumptions of varying environmental changes (increased water temperatures), accessibility of fisheries, intensity of demand by a growing human population, and availability of alternative substitutes under four scenarios (see Section 2.3). The FMFO model was developed by Christian Mullon using network economics that couple the equilibrium of the supply and demand of commodities with specific deterministic rules which can be altered under different scenarios (see Mullon et al. 2009, 2016).

The production side of the model is made up of fish stocks, fishing fleets and transformation industries. The fish stocks are described by the intrinsic growth rate, carrying capacity, catchability and quota. The fleets are defined by: investment rates, depreciation rates and capital remuneration rates and along with costs are used to calculate profit for each producer. The transformation links are described by the costs of converting catch to fishmeal and fish oil as well as shipment costs. The consumption side is described by the intensity and flexibility of demand for the FMFO commodity.

The FMFO model is used to project the fishmeal and fish oil prices from 2013 until 2050 under four scenarios. The model was run at the global scale due to the FMFO market being naturally geographically dispersed and uses data that accounts for 80% of production and consumption. A number of databases were used to collate the information required to update the FMFO model. The latest five years of data (2009–2013) were averaged to provide a more accurate account of current production while avoiding inter-annual variability. Fish production data was downloaded from FishStat, international trade was downloaded from Comtrade and major species fished by country from Sea Around Us.

2.2 Input-output (IO) model

The Input-Output (IO) model is used to estimate the whole-economy impact of changes in the supply of aquatic commodities. The IO tables, on which it is constructed, provide a succinct overview of the structure and operation of an economy and allow a variety of multipliers to be used to quantify the direct and indirect impacts from a change in the outputs of a sector.

The multipliers are derived from the Leontief inverse of the IO table. The Leontief inverse is calculated following the established and standardized approach developed by Wassily Leontief and produces a number of Leontief coefficients, l_{ij}, for each sector. The output multiplier for sector *j* is calculated by summing the Leontief coefficients of the j^{th} column of the table. The output multiplier, m(o), for sector *j* can then be stated as: $m(o)_j = \sum_{i=1}^{n+1} l_{ij}$.

The effects of a change in the final demand of a sector and its impact on income from employment (I_{eff}) can also be calculated as follows: $(I_{eff})_j = \sum_i^{n+1} v_i l_{ij}$, were v_i is the compensation of employees for sector *i*.

The wider economic (direct and indirect) impacts from a change in output in the fisheries and aquaculture sector under the four scenarios are then calculated by multiplying the output multiplier and income from employment effect accordingly.

The IO tables are constructed by national statistic offices worldwide according to the internationally agreed System of National Accounts standards (UN 2008). The tables are published approximately every five years and contribute to core national accounts. The IO tables are populated with data collected from annual business surveys which includes imports and exports, compensation of employees, taxes and value added. Input-output tables for five EU countries (Spain, Netherlands, UK, Denmark and Germany) sourced from the Eurostat website is used.

2.3 Climate-socio-economic scenarios

Four contrasting scenarios were created in the larger CERES (Climate change and European Aquatic Resources) project funded under the Horizon 2020 programme. The scenarios combine climate-driven changes in the marine and freshwater environments with political, economic, social, technological, legal and environmental (PESTLE) changes. The projected changes in these elements are based on two Representative Concentration Pathways (RCPs) developed by the IPCC and the Shared Socioeconomic Pathways (SSPs) also developed by the IPCC (Pinnegar et al).

The four scenarios of alternative futures include:

(i) World markets (WM): representative of high consumerism, little regulation, high fossil fuel dependency, highly engineered infrastructure and ecosystems.

(ii) National enterprise (NE): national isolation, protectionism, high resource intensity, low investment in technology, low environmental protection.

(iii) Global sustainability (GS): high priority for environmental protection, cooperative society, low resource and fossil fuel dependency.

(iv) Local stewardship (LS): support small scale regional economies, moderate population growth, no overarching strategy to manage ecosystems.

Running the FMFO and IO models under these same scenarios will provide consistency and transparency in assumptions and allow the models to be linked through the aquaculture sector.

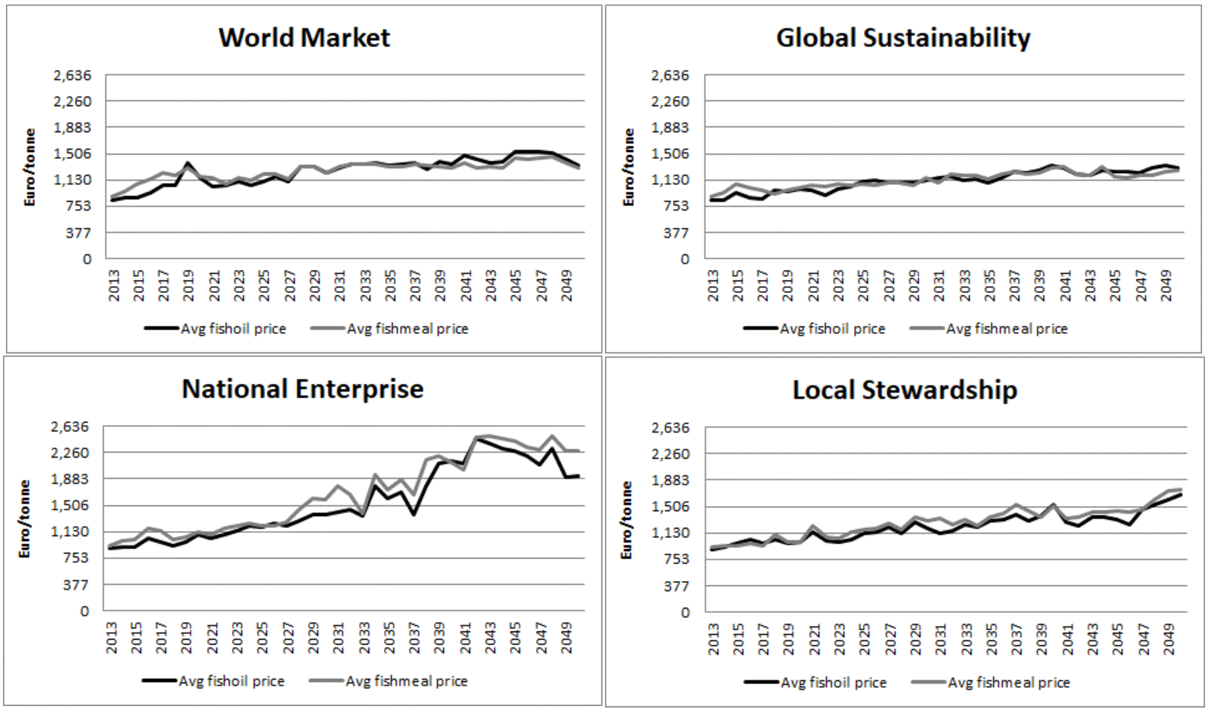
3. Results

3.1 FMFO prices

The projected FMFO prices by scenarios are presented in Euro/tonne for 2013-2050 (**Error! Reference source not found.**1). Overall, the National Enterprise (NE) scenario generates the highest prices for fishmeal at €2,282 and fish oil at €1,921 in 2050, followed by the Local Steward (LS) scenario. The World Market (WM) and Global Sustainability (GS) show similar pricing structure with the GS producing the lowest and most stable (lowest variability) pricing of all four scenarios. Under the GS, fishmeal prices reach a maximum of €1,269 and fish oil prices reach a maximum of €1,306 in 2050.

One of the main explanatory variables of these observed price differences between the global and local scenarios, is the assumption of demand flexibility which accounts for the presence of substitutes or alternatives to the fishmeal and fish oil commodities. In the NE and LS scenarios, the flexibility of FMFO is decreased assuming that there are few alternatives while the opposite is imposed in the WM and GS scenario and flexibility increased under the assumption of alternatives being available.

Figure 1: Projected FMFO prices by scenario (Euro/tonne)



3.2 IO results

Economic impacts of changes in the price of aquaculture feed and production of aquaculture systems under the four scenarios for Spain, Netherlands, UK, Denmark and Germany are estimated. It can be seen from the results that economy wide impacts of changes to fisheries and aquaculture in 2050 can reach up to a loss of €228 million (Table 1). Small gains are also seen and can reach €3 million. These losses and gains are all relative to the size of the current fishery and projected impacts from climate change.

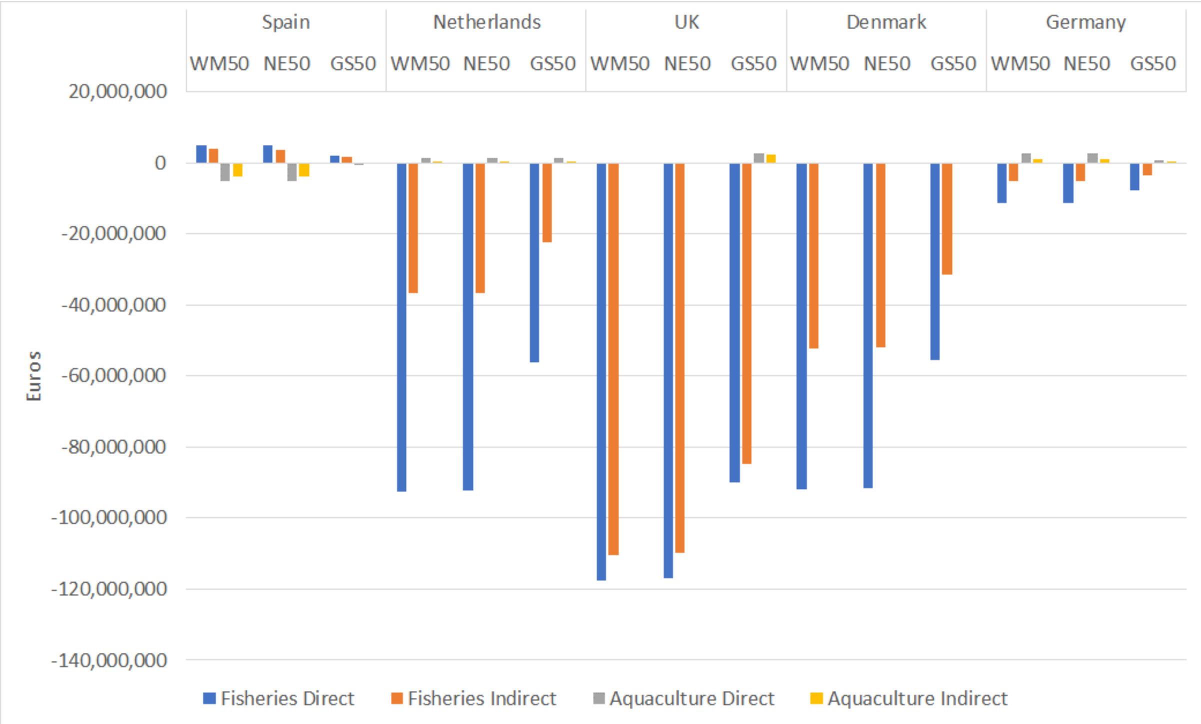
Table 1: Economy wide impacts on value of output and income

	Change in economy wide output (Euro millions)				Change in economy wide IfE (Euro millions)			
	WM50	**NE50**	**GS50**	**LS50**	**WM50**	**NE50**	**GS50**	**LS50**
Spain	0.03	-0.38	3	na	0	0	1	na
Netherlands	-127	-127	-77	-76	-21	-21	-13	-13
UK	-228	-227	-170	-176	-34	-34	-25	-26
Denmark	-144	-144	-87	-85	-26	-26	-15	-15
Germany	-13	-12	-10	-10	-26	-26	-15	-15

Income from employment is also expectedly impacted. Apart from Spain, all other economies can expect a decrease in income from employment between €13 million to €34 million circulating in the economy. These results combined with the total output provide a generally negative view of the economic returns that can be expected by countries in Europe reliant on the waters in the North East Atlantic and North Sea small pelagics fisheries under climate change.

The results in **Error! Reference source not found.**1 presents economy wide impacts on the economy. If only the impact on the fisheries and aquaculture sector was considered under climate change, then in some cases up to 80% of additional positive or negative impacts would be overlooked. This is most evident when considering possible losses (Figure 2). In the case of the UK, reduced outputs of the fisheries and aquaculture sector under the WM scenario would not only produce a loss of €117 million to the sector itself but would results in an additional €110 million loss to the rest of the economy. In total, the UK economy would face a loss of €227 million.

Figure 2: Direct and indirect impacts in Euros across the four scenarios until 2050



Scenarios are: World Market to 2050 (WM2050), National Enterprise to 2050 (NE2050), Global Sustainability to 2050 (GS2050) and Local Stewardship to 2050 (LS2050).

4. Discussion

4.1 Feedstock prices

Europe's finfish aquaculture production relies on fishmeal and fish oil (also referred to as feedstock) sourced from both within the EU but also from countries further afield, such as Chile and Peru. In 2018, the EU imported approximately 50% of its total demand for feedstock. The main suppliers of fishmeal were Norway, Iceland and the Faroes, while the main suppliers of fish oil were Peru, Norway and the US (EUMOFA 2019).

The fishmeal and fish oil price projections are based on the particular assumptions of a changing environment and catchability of fisheries under climate change coupled with variations in the scale and intensity of demand. The prices are projected to increase in all scenarios to varying degrees. The National Enterprise (NE) sees the largest price increase for fishmeal and fish oil reaching €2,260/tonnes while the lowest increase is €1,269/tonnes under the Global Sustainability (GS) scenario. A combination of high latitudinal shifts in fisheries, a growing human population consuming increased levels of seafood and lower assumed co-operation globally sees these high prices in NE while the relatively low-level price in the GS scenarios is based on more moderate latitudinal shifts, growing human population with lower seafood demand and more cooperation in trade.

Uncertainty of feedstock prices and the range to which they can vary will increase exposure of aquaculture farms in time. These insights provide the basis for initiating and contributing to mitigation and adaptation strategies. Efforts are already being made from a number of quarters, including variation in quotas for managing small pelagic fisheries and this can be extended to manage changes from climate change.

4.2 Economy wide effects

It is shown from estimations from an economy wide perspective that impacts on economies can in some cases double. The scale of these impacts highlights the need for more holistic approaches in considering the impacts of climate change; the move from sector specific to economy wide impacts. All countries reviewed, with the exception of Spain, will sustain losses from climate change and its impact on fisheries. The relative contribution between the direct (sector specific) and the indirect (economy-wide) impacts vary by country due to their differing economic structure. This insight is useful for adaptation strategies of countries. For example, it is clear that of all the countries analysed, the UK will be impacted the most from changes in fisheries. A loss of €117 million to the seafood sector will equate to an additional €110 million to the rest of the economy, culminating in a total loss of €227 million.

Reducing the direct impacts to the UK economy would require its structure to become more flexible to potential changes in the fisheries sector. This could be achieved by exploring alternative management options and sale of different fish species in the future. The discussion can be further extended to other supply chain industries and explore how the dependency of these industries could be reduced by increasing links to alternative sectors or diversify their operations.

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