Blue economy with a CGE framework: an analysis of the possible role of seafood within sustainable diets

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Introduction

One of the greatest challenges is the coming decades is how to feed a fast growing world population in a sustainable way that does not threaten the carrying capacity of the Earth. According to the Eat-Lancet report on healthy diets seafood would be a particularly promising soured of proteins. This would include both wild capture fish as well as aquaculture fish and seaweeds.

However this would require an increased consumption and therefore production of fisheries and aquaculture products. Wild capture fisheries is limited by the availability of fish stocks which world wide have been under pressure due to overfishing; global warming and changing marine environments. Therefore it is unlikely that wild capture fisheries can grow to satisfy increased demand for proteins. It can be expected that aquaculture and seaweeds should grow to meet future demand. However it is a question whether these sectors can grow enough and whether policies could help these sectors develop further.

In this paper we applied the blue economy module in MAGNET to calculate the macro-economic impacts of including an EAT-Lancet diet worldwide. We will show the expected impact on the reduction of livestock, the change in feed sectors and the expected increase in demand for different food products including fish products and seaweed. We will also focus on the expected impacts on emissions and the affordability of food worldwide. Further more we will specifically look at the EU and analyse what kind of impact a switch to a more sustainable diet including seafood would do for the self-reliance and trade balance of the EU.

Methodology

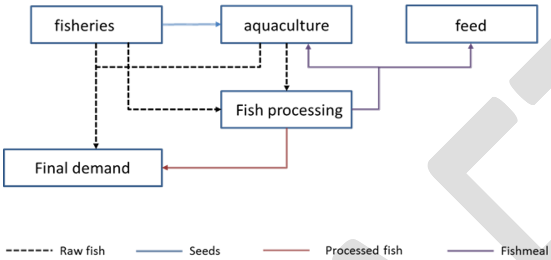
The Modular Applied GeNeral Equilibrium Tool (MAGNET) is a recursive dynamic, multi-regional, multi-commodity CGE model, covering the entire global economy. As with other CGE models, MAGNET explicitly represents the economic linkages across the sectors of each regional economy. This is particularly important when analysing policy effects in sectors that are vertically linked with each other, such as fertilisers, agriculture and biofuels. It is built upon the GTAP model (Hertel, 1997) and is the successor of the LEITAP model which has been widely used for policy analysis (Banse et al., 2008; van Meijl et al., 2006; Nowicki et al., 2009, Woltjer, 2011). The MAGNET model is modular in nature and extends the GTAP model through the addition of a number of policy-relevant modules. For this study the focus is on the blue economy module in MAGNET.

Blue economy module MAGNET

This module allows analysis in the context of the "blue economy", sustainable management of natural resources and global food security. MAGNET has split the GTAP fish sector (fsh) into six sectors. One wild captured fish sector; five aquaculture sectors based on fish families, i.e., diadromous fish (salmon and trout), fresh water fish (carp, tilapia, pangasius, other fresh water fish), farmed marine fish (sea bass and other marine fish), molluscs (clam, mussel, oyster) and crustaceans (shrimp, other shellfish); a seaweed sector. Apart from the aquaculture sectors, MAGNET has also modelled a fish processing sector split from the other food processing (ofd).

According Eurostat, in 2014, these sectors contribute to 93.6% of the added value generated by the aquaculture sector, i.e., diadromous fish (37.8%), fresh water fish (4.5%), farmed marine fish (28.1%), molluscs and crustaceans (23.2%). Remaining 6.4% of total added value mostly come from the production of algae and aquatic plants.

The aquaculture and fisheries sector in MAGNET is interconnected. Wild capture fisheries delivers seeds to aquaculture sectors. Feed is explicitly modelled and attention is given to the competition between aquaculture and cattle sectors for available feed. Both wild capture fisheries and aquaculture can deliver directly to final demand or to processed fish sector which will then deliver to final demand.



Modelling of Seaweed

The seaweed sector is new in the blue economy module in MAGNET. There is considerable interest in Europe in the potential of seaweed as source of food, feed and biomass for a biobased. Various research programmes study the potential applications of seaweed, numerous small and larger companies venture into the production and processing of seaweeds and policies to stimulate growth of the seaweed sector are developed. Among the foreseen applications of seaweed is use as food although no specific targets on seaweed consumption have yet been formulated. Within MAGNET we used the FAO production and trade data to include a seaweed sector.

To implement seaweed in MAGNET, data was collected from the FAO about production and export value of seaweeds in million euros. The FAO data about production and trade did not match very well. For several countries, the FAO data reported more seaweed exports than production, see Figure 1. In these cases we assumed that the production data of FAO is incorrect and we adjusted the total production in a country to match the export.

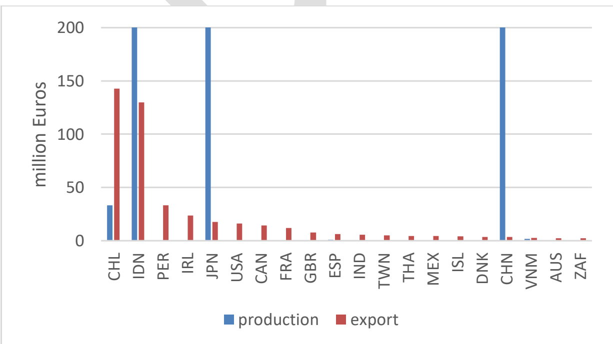


Figure 1 Production versus export of seaweed, 2014, USD million

Source: https://www.fao.org/fishery/statistics-query/en/aquaculture

The cost structure for the new seaweed sector is based on Zhang et al. (2022), which provides cost data on Danish seaweed farms. The data is used to calculate shares of different types of inputs used in seaweed farming. Sectors in MAGNET demand primary (land, labour, capital, natural resources) and secondary inputs (all other material inputs) to produce output. Not all sectors use all inputs, though. For example, the seaweed sector does not use agricultural land as an input. In absence of comparable data for all countries in the NSR regions, Danish data is applied to all NSR countries. The average cost structure of seaweed production is shown in Figure 2. Almost 57% of the costs are labour costs. Capital and seed costs account for 35% of the production costs. The rest is maintenance, harvest and various other costs.

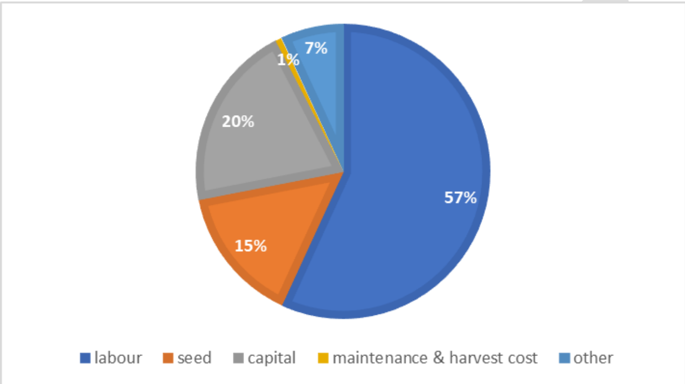


Figure 2 Production cost structure of seaweed

Source: Adapted from Zhang et al. (2022).

The data on seaweed production in MAGNET comes from FAO (Food and Agriculture Organization) Food Balance Sheets 2014. FAO does not, however, provide seaweed production data for the Netherlands and Great Britain (two of our focus countries) and data for these had to be imputed (see Appendix). The status of seaweed production in the NSR in 2020 is shown in Figure 2. In terms of share in NSR production, Norway is the biggest producer, followed by France, Denmark and Ireland. Production in the Netherlands is the lowest in the group.

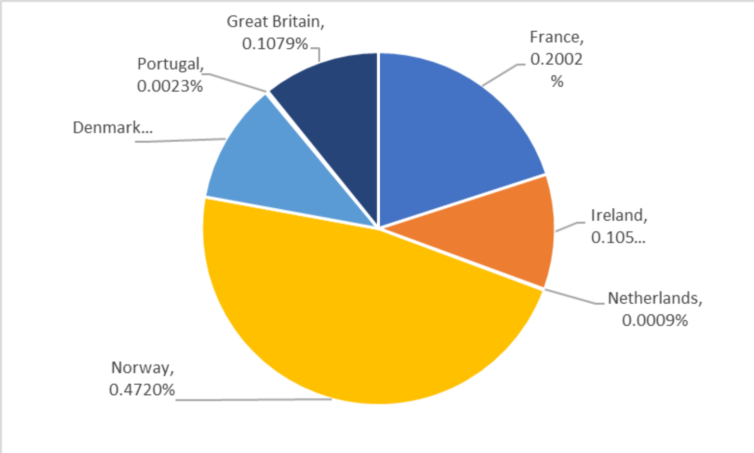


Figure 3 Share of selected NSR countries in seaweed output (% of world production)

The output thus produced is demanded by domestic consumers, consumers abroad (by trade channel) and also as a secondary input by other sectors. The figure below shows the demand structure used in MAGNET. The demand structure used is based on expert opinion. Most of the seaweed produced is demanded by consumers (78%). Other uses are in processed food (14%) or biofuels (8%).

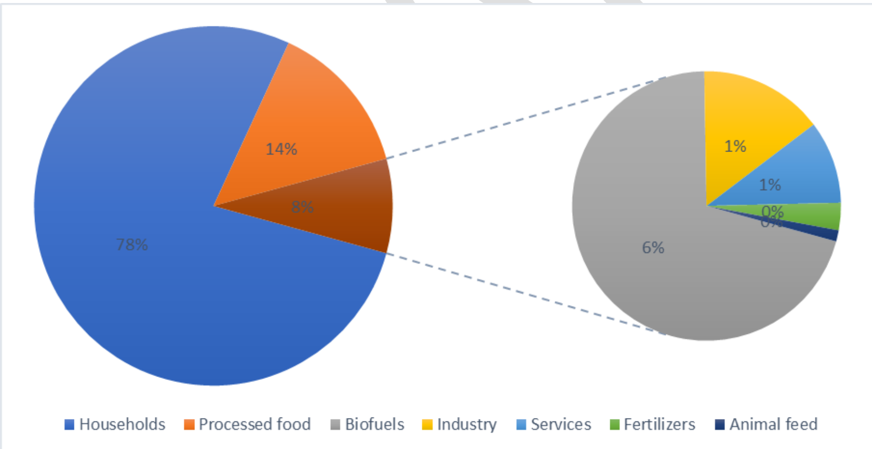


Figure 4 Demand structure of seaweed

MAGNET calculates household nutrition indicators, using the flow of primary agri-food commodities through the global economy from farm to fork. It has been incorporated as a nutrition module in MAGNET. The method of tracing nutrients through the food system allows for making agriculture, the food supply chain and the economy as a whole nutrition-sensitive in scenario analyses. In this study the nutritional values of seaweed are added to the model. As we have only one seaweed sector in MAGNET we use average nutritional values of several types of seaweed (category aquatic plants in FAO, 2014).

We assume the following values: on calorie (0.00054), protein (0.000028), fat (0.000006) and carbs (0.0000935) per kilo of physical quantity. By combining these values with FAO Food Balance Sheet data on physical production in tonnes of aquatic plants (FAO, 2014) we can calculate the total nutritional value of seaweed consumption.

Due to missing data for the Netherlands (NL) and Great Britain (GBR) in the FAO Food Balance Sheet data, we had to make certain assumptions to calculate physical production units associated with the value of production (dollar terms) in the model. This was done in three steps as follows:

- Step 1: For the countries that do have FAO data on physical production units, we calculate price (dollars/tonne of seaweed).
- Step 2: Next, we use price data from these countries as proxy for price in the countries with missing physical production data. Based on type of seaweed produced in the country we used the Portuguese price for the Netherlands and the average of prices in France, Ireland, Norway and Denmark to calculate the price in Great Britain.
- Step 3: The calculated prices along with the value of production in the country are used to calculate the physical quantity of seaweed production in the Netherlands and Great Britain. This quantity is used to replace the missing data.

The nutritional value of seaweed production in different regions is later used by the model to determine the nutritional value of seaweed consumption for both domestically produced seaweed and imported seaweed.

Results

Baseline

We used the model to analyse the results of an EAT Lancet diet on the production of fish and seaweed. The eat lancet diet scenario is evaluated in contrast with a baseline scenario without any assumptions on seafood and seaweed production or demand growth being made. MAGNET is calibrated to version 11b of the GTAP database (Aguiar et al., 2023) with base year 2017. The baseline is split into an update period (2017-2019) and a projection period (2020-2050). It is based on a number of assumptions for which additional sources were used. Most importantly, these include assumptions on future developments in GDP and population. Estimates of real GDP and population growth for the period 2017-2050 are taken from OECD-FAO (2013) following the Shared Social Pathways middle of the road scenario (SSP2). Typically, exogenous projections of GDP and population result to be the main drivers of the projections, due to their role in conditioning expected income per capita trends by region. These trends drive final demands, which in turn motivate changes in supply activities and investment. The macro shocks are shocks are supplemented with additional land and forestry productivity shocks, agricultural and biofuels policy. Growth in yields is taken from the IMAGE model suite (Kram and Stehfest, 2012; OECD, 2012; Stehfest et al. 2014) and is based upon FAO projections up to 2050 (Bruinsma, 2003).

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Additional minor assumptions were added in other to ensure realistic projections for the base scenario. In particular, the added assumptions concerned :

- The feed sector: The feed input shock is an efficiency towards increased feed efficiency use over time. The data at the basis of this assumption come from the IMAGE model. This addition is similar on the assumption made for land, whose productivity change over time are also retrieved from IMAGE.
- The nuclear sector: The production of nuclear energy is fixed to current (base year) levels i.e. 2017. This assumption is driven by the fact that choices in expanding nuclear production is mainly political and not driven by profit or efficiency as it would be in an unconstrained MAGNET

context. Therefore, this assumption avoids the possibility of an unrealistically high increase in nuclear energy production in the near future without changes in the political status quo.
- Expansion in grassland is Sub Saharan Africa. To avoid extensive (unrealistically high) potential increases in grazing area and overall land use change, the possibility of expand grazing area is constrained.
- The biofuel sector. Biofuel ration is set as fixed. First generation biofuels are not assumed to increase over time since there are political constraints acting on these commodities (due to competition for production inputs with food producing sectors).
- Common Agricultural Policy transfers: The accumulation of "first pillar" budget is included in the baseline, as is considered business as usual for the European Union mid-term future.

GDP and population are among the key drivers that shape the business-as usual scenario. Worldwide economies are projected to expand between 40% (EU) and 270% (Africa) from 2019 to 2050 (Figure 5). Population growth is expected to be more modest between -2% (EU) and 80% (Africa). Yield are also expected to grow in the period 2019-2050. Again the growth will be the highest in Africa (85%) and the lowest in EU, Asia and North America (around 20%).

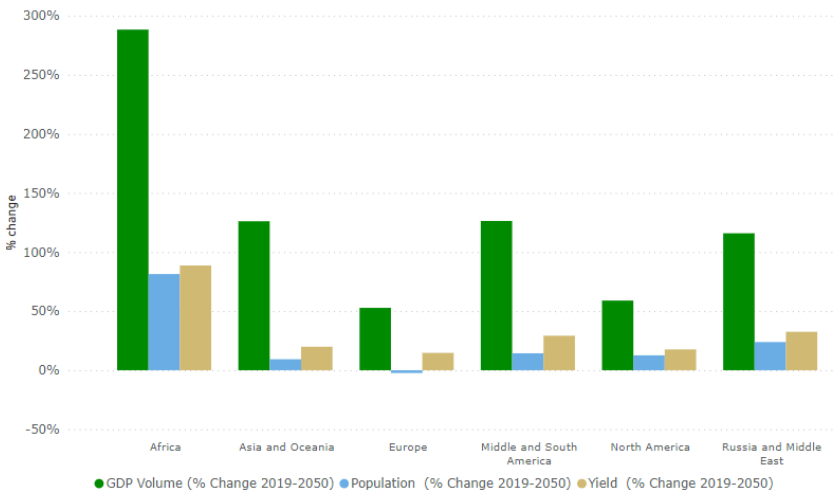

Figure 5 Macroeconomic changes 2019-2050

Figure 6 depicts a selection of indicators to assess the progress in the baseline in different dimensions such as the economy, inclusivity, food security and the environment. Wages in agriculture and overall added-value in the food systems are mostly projected to grow in the future, particularly in the case in European, Asian and Oceanic countries. In Africa, wages in agri-food systems are projected to decline in the period 2019-2050. Food and nutrition security indicators are foreseen to slightly deteriorate over the analysed period. Africa is expected to become more dependent on food imports to source its national consumption, other regions remain very stable in their self sufficiency. It is also expected that diets without any policies would become unhealthier. Fruits and vegetables will slightly decrease their share in food consumption, whereas sugar will increase its corresponding share. Regarding the environmental indicators, there will be a slight reduction in land use even though fertilizers application in agriculture is expected to go down substantially. Only in Africa the use of fertilizers is expected to increase significantly. The overall decline in fertilizer use in most of the world is because it is assumed that yields will increase due to improvements in varieties (genetic improvements) and more optimal use of inputs and other management practices, which is a continuing improvement of observed historic yield trends. While there is an improvement on the fertilizer based environmental indicator, the indexes based on land use and emissions signal a negative expected result.

aggregation	Increase in: Wages in agriculture	Added-value in food system	Self-sufficiency in agri-food	% fruits&veg in energy intake	Reduction in: % sugar in energy intake	Land use	Fertilizer application	Total GHG emissions	Agri-food GHG emissions
Russia and Middle East	20	17	1	4	3	-1	9	-50	-37
North America	24	3	-1	-2	-8	-1	34	-15	-16
Middle and South America	22	8	10	2	2	-20	24	-56	-73
Europe	37	-7	4	0	1	6	37	-10	-29
Asia and Oceania	45	-12	1	-4	-4	-1	39	-27	-45
Africa	-25	36	-18	0	5	-11	-88	-117	-68
Total	**28**	**-2**	**-1**	**-3**	**2**	**-6**	**29**	**-35**	**-49**

Figure 6 Multidimensional assessment of the future in the business-as usual scenario. Growth rate of selected indicators, 2019-2050.

Note: Growth rates are expressed in terms of the ideal direction. Thus, when growth in an indicator has negative consequences (e.g., increase in emissions), it is expressed in terms of "reduction in" as seen on the top (i.e., a positive number means a reduction in such indicator). For example, in the case of Russia and the Middle East for the Total GHG emissions indicator, a 50% increase in emissions is projected over the period 2019-2050.

Source: MAGNET Model.

Asia and in particular China produce about 90% of all fish products in the world as Figure 7 shows. From the different fish products, wild fish is still the largest category produced. This is not expected to change in the period 2019-2050. However as wild fish production is limited by the available fish stocks, the growth in wild fish production is limited. Aquaculture is growing much faster then wild fish production.

Seaweed production is fairly limited compared to the other fish products. Only in Asia there is a significant production.

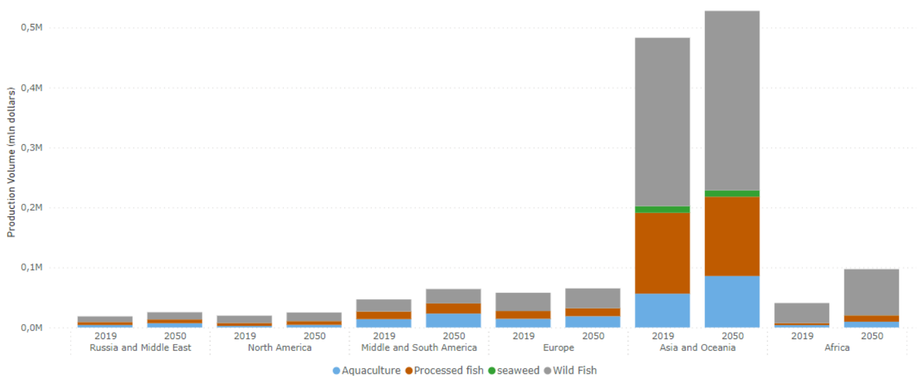

Figure 7 Production volume fish products, 2019-2050.

Source: MAGNET Model.

While Asia is a large producers of fish products, they mostly produce for the domestic market. Exports in fish products is limited. Figure 8 shows the change in trade balance for fish products between 2019-2050. The model does not predict large changes in the trade balance of fish products. Regions that are net importers are expected to stay net importers, and the same holds for next exporters.

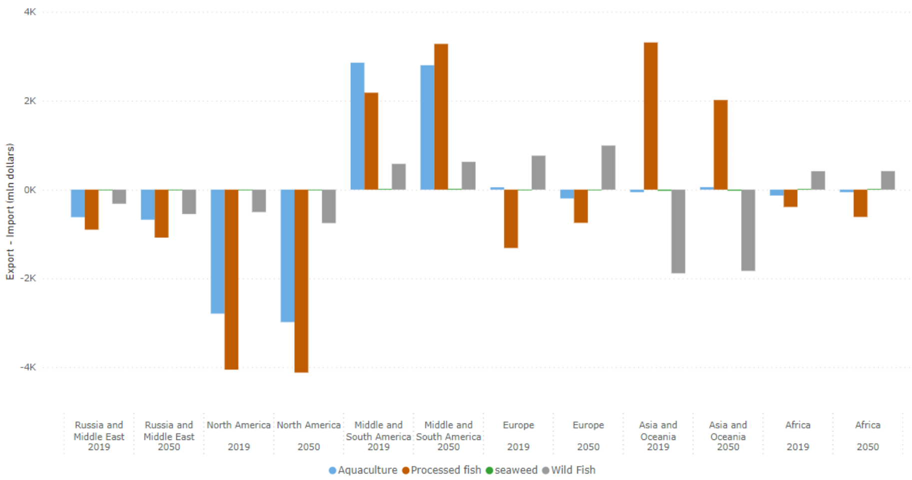

Figure 8 Trade balance fish products, 2019-2050.

Source: MAGNET Model.

Without policies, diets are expected to become less healthy. Consumption of red meat specifically is expected to increase in almost every region of the world as Figure 9 shows. While fish consumption is expected to increase, the share of fish consumption compared to meat consumption remains low.

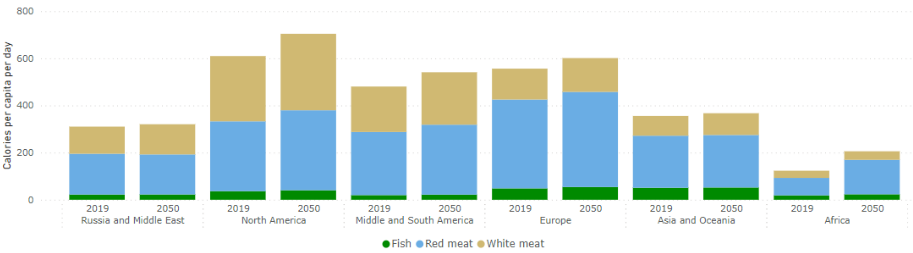

Figure 9 Consumption fish and meat products, 2019-2050.

Source: MAGNET Model.

As the production of wild fish is restricted in growth due to availability of fish stocks, consumption of fish is mainly caused by an increased consumption of aquaculture fish (Figure 10). Only in Africa, consumption of wild fish also increases. Seaweed consumption increases around the world however as the initial consumption is fairly limited compared to other fish products, the absolute value of seaweed consumption remains low.

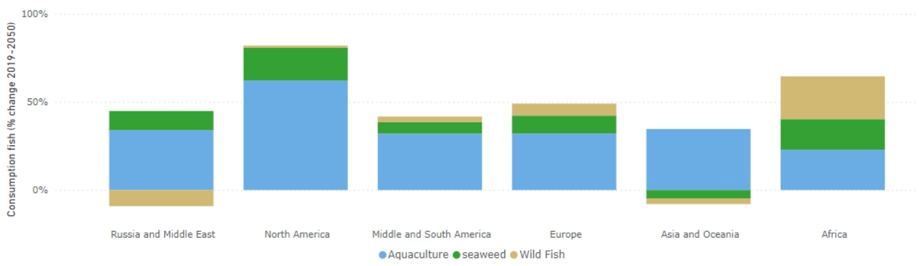

Figure 10 Changes consumption fish products, 2019-2050.

Source: MAGNET Model.

Eat-Lancet Scenario

We applied the blue economy module in MAGNET to calculate the macro-economic impacts of including an EAT-Lancet diet worldwide. We will show the expected impact on the reduction of livestock, the change in feed sectors and the expected increase in demand for different food products including fish products and seaweed. We will also focus on the expected impacts on emissions and the affordability of food worldwide. Further more we will specifically look at the EU and analyse what kind of impact a switch to a more sustainable diet including seafood would do for the self-reliance and trade balance of the EU.

-Forthcoming-

Conclusions

-forthcoming-

References

Aguiar, A., et al.,The Global Trade Analysis Project (GTAP) Data Base: Version 11. Journal of Global Economic Analysis, 7(2), (2023). https://doi.org/10.21642/JGEA.070201AF

Bruinsma, J. (ed) (2003) *World agriculture: Towards 2015/30, FAO Perspective*, London: Earthscan and Rome: FAO.

Corong, E. L., Hertel, T. W., McDougall, R., Tsigas, M. E., & van der Mensbrugghe, D. (2017). The Standard GTAP Model, Version 7. Journal of Global Economic Analysis, 2(1), 1–119. https://doi.org/10.21642/JGEA.020101AF

Hertel, T.W. (Ed.) (1997). Global Trade Analysis Modelling and Applications, Cambridge University Press, Cambridge.

Huang, H., F. van Tongeren, J. Dewbre and H. van Meijl (2004), "A New Representation of Agricultural Production Technology in GTAP", Paper presented at the 7th Annual Conference on Global Economic Analysis, Washington DC, USA.

Kram, T. and E. Stehfest (2012). The IMAGE model suite used for the OECD Environmental Outlook to 2050. PBL Note 500113002, PBL Netherlands Environmental Assessment Agency, The Hague. Available at http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2012-the-image-model-suite-used-for-oecd-environmental-outlook-2050.pdf, 07/06/2012.

O'Neill et al., "The roads ahead : Narratives for shared socioeconomic pathways describing world futures in the 21st century," Glob. Environ. Chang., vol. 42, pp. 169–180, (2017), doi: 10.1016/j.gloenvcha.2015.01.004.

OECD (2003), *Agricultural Policies in OECD Countries, Monitoring and Evaluation 2000*, OECD Publishing, Paris.

OECD (2012). OECD Environmental Outlook to 2050, The Consequences of Inaction. OECD Publishing, Organisation for Economic Cooperation and Development, Paris.

Stehfest, E., et al. Integrated Assessment of Global Environmental Change with IMAGE 3.0. Model description and policy applications, The Hague: PBL Netherlands Environmental Assessment Agency (2014).