TRADE4SD

Fostering the positive linkages between trade and sustainable development

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Report on linking SDG indicators with models in the TRADE4SD toolbox

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List of abbreviations

AEZ	Agro-Ecological Zone
CAP	Common Agricultural Policy
CES	constant elasticity of substitution
CGE	computable general equilibrium
EFA	ecological focus areas
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FLI	Food Loss Index
GAMS	General Algebraic Modeling System
GDP	Gross Domestic Product
GHG	Greenhouse gas
GTAP	Global Trade Analysis Project
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Co-operation and Development
PE	partial equilibrium
PPI	Producer Price Index
SDG	Sustainability Development Goals
SDIs	Sustainable Development Indicators
SSPs	Shared Socio-Economic Pathways
TRQs	tariff-rate quotas
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
WP	Work package

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1 Introduction

Building on Huan-Niemi *et al.* (2022) and Jambor *et al.* (2022), this report gives an overview on how different indicators within Sustainability Development Goals (SDG) will be covered in the quantitative, model-based analysis in WP3, which are a part of the TRADE4SD toolbox. The TRADE4SD toolbox consist of four models, namely CGEBox, MAGNET, AGLINK-COSIMO, and AGMEMOD. Each model has its own strengths, which will be employed to analyse different SDG targets and the policies contributing to them.

The aforementioned models will base on the previous conducted work. However, several extensions are required to extend the coverage of SDG indicators and policy instruments impacting these SDG indicators. Consequently, this deliverable provides an overview of current modelling of SDGs related policy instruments and indicators to measure the success or degree of progress to reach different SDG targets.

Therefore, the coverage of each model with respect to SDG indicators and policy instruments impacting these SDG indicators are identified. Building on this, the need for further model development and improvement to enable existing models to address the trade and sustainability impact of new policy options is defined. Each model will be extended so that their already developed strength is further improved. Hence, each model will address different SDG indicators and related policies.

The envisioned extensions of the models will allow to conduct scenario analysis to provide a better understanding of medium- to long-term consequences of changes in the agricultural sector due to: a) new policy implementations, b) contributing to SDG indicators, and c) reaching SDG targets.

This text is the first deliverable D3.1 of work package 3 in TRADE4SD. As a 'living document', it does not represent the conclusion of the work of incorporating and mapping sustainability indicators in partial and general equilibrium models. In this paper, the authors involved described the current status of our intense work, which will not only summarise the immediate results of WP3, but also incorporate the results of other work packages.

For example, a Delphi study is currently being conducted in WP4 to investigate the attitudes of stakeholders to the importance of the various aspects of sustainability. From this study, which is divided into different stages of online-based surveys, important results will flow into the model-based analyses in WP3. One result of these surveys will be a prioritisation of different aspects of sustainability. This ranking will also have an impact on the design of the model-based analyses in WP3 and thus also on the selection of suitable indicators.

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2 Models, SDG indicator coverage, and policy instruments

This chapter presents the sustainability indicators represented in the quantitative models in TRADE4SD. The coverage is based on the identified SDG indicators in Jambor et al. (2022) which are relevant for agriculture and trade. Further, this chapter is divided into the depiction of these indicators in the various models of the TRADE4SD toolbox, CGEBox, MAGNET, AGLINK-COSIMO and AGMEMOD. This way of presentation is the result of task division envisaged in TRADE4SD for mapping the various aspects of sustainability in the quantitative models involved. While the aspects of environmental protection are examined in more detail in the CGEBox model, the MAGNET model focuses the analyses on questions around the social aspects of sustainability. The two partial models AGLINK-COSIMO and AGMEMOD take a detailed look at the economic aspects of sustainability.

All four models involved are economic models and endogenously represent the 'classical' variables of production, consumption, trade and equilibrium prices. Therefore, it is to be expected that there will be 'cross-cutting' results across the models in the scenario analyses, the focus of which, however, will then lie in the above-described division of labour in the analysis of sustainability aspects. Therefore, this deliverable should provide more information on how the different aspects of sustainability are to be captured and 'measured'.

After a brief introduction to SDG coverage in various models (Section 2.1), this chapter gives an overview per model in the TRADE4SD toolbox on the coverage of SDG indicators, related policy instruments, and the envisaged extensions (Section 2.2 to 2.5).

2.1 SDG representation in models

The United Nations Department of Economic and Social Affairs (UNDESA) and the United Nations Development Programme (UNDP) have pioneered a series of modelling tools. Early initiatives included economy-wide modeling and microsimulation methodologies. Five quantitative modelling tools are being used by UNDESA and UNDP to help countries assess sustainable development policy options. One of them is a microsimulation model which offers insights for policies to eradicate poverty, reduce inequality, enhance food security and broaden access to energy, among others. The technique has been applied to policies related to taxes or subsidies, cash or in-kind transfers, and expanded access to modern energy, among other examples.

However, apart from the data availability challenges of such microsimulation models, they are not sufficiently ‘integrated’, i.e. they do not represent the national level and global repercussions and interlinkages of the various categories of sustainable development, especially when it comes to the social aspects of sustainability.

As Allen, Metternicht and Wiedmann (2016) concluded after reviewing the strengths and weaknesses of 80 contemporary modelling tools in the context of national development planning for the SDGs:

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'*In terms of sustainability dimensions, the most common approach was the integration of economic and environmental variables in the model. [...] A total of 54 models (or 68%) integrated these two dimensions to varying degrees, highlighting the rapidly growing catalogue of economy-environment models. The social dimension of sustainable development is by far the least addressed, with only 17 models (or 21%) including social variables within their modelling framework, and often with very limited coverage (most commonly a few health-related or nutrition-related variables). The modelling of social variables can therefore also be considered as an important gap in modelling capabilities*.'

More concretely they point out that '*key gaps or thematic issues requiring further model development include poverty, health, education, gender, inequality, sustainable consumption and production, biodiversity and governance-institutions.*'

They also observed that *'only eight models (10%) met the two screening criteria of 'policy relevant' and 'integrated'. The shortlist comprised one top-down CGE model (MAGNET), one top-down system dynamics model (Polestar), and six hybrid models (IMPACT; International Futures; Threshold 21; EC4MACS; InVEST; and LowGrow).'*

Allen, Metternicht and Wiedmann (2016) illustrates and reveals the challenges to use and develop further the MAGNET model in the direction of integrating social effects and their feedbacks to macroeconomic categories. Here, the modelling work planned in TRADE4SD will contribute by systemically considering all three aspects of sustainability – economic, social and environmental.

2.2 CGEBox

CGEBox provides a flexible, extendable and modular code basis for computable general equilibrium (CGE) model in General Algebraic Modeling System (GAMS) based on the GTAP data base. Its core draws on the Global Trade Analysis Project (GTAP) Standard model version 7 in GAMS by van der Mensbrugghe (2018). CGEBox can configure differently structured single country and global CGE models in comparative-static or recursive dynamic mode, supporting flexible aggregation by region, product, sector and factor from the GTAP Data Base. More specific details about CGEBox, its method and mechanisms are described in the official model's documentation (Britz, 2021).

CGEBox implements different modules which replicate variants of the GTAP model or provide new extensions which can be combined in applications:

- **GTAP-AGR:** intermediate demand nests for feed use in livestock production and for primary agricultural products into food processing sector; a split-up into an agricultural and a non-agricultural household.
- **GTAP-E**: Multi-stage nesting for energy-capital composite in production and demand nests for energy use.
- **GTAP-AEZ**: Sub-regional land markets by up to 18 Agro-Ecological Zone (AEZ) per model region, with physical land in hectares based on CES/CET structures, supports both the 2007, 2011 and GTAP V10 releases of the AEZ land use data base, uses

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volume-preserving CET transformations, land supply from crop land buffer based on land supply elasticities, carbon stock accounting including conversion of natural vegetation to land in economic use.

- **myGTAP**: Support for several private households, replacement of regional household approach by separate accounts for the different agents. Can be used to define, for instance, a household drawing income from factor use in agricultural and non-agricultural activities.
- **GMIG**: Bi-lateral migration of labour force and population, remittances.
- **GTAP CO_2 / NonCO_2 / air pollution / energy use (oil equivalent) reporting**: with the possibility to tax user defined product/activity combinations of CO_2 (equivalent) emissions, including process emissions.
- **GTAP-NUTS2**: Dis-aggregation of national production and factor markets to sub-regions.
- **GTAP-TIVA**: Post model generation of a global Leontief-inverse to derive Trade-In-Value added indicators and to attribute global changes in CO_2 / non-CO_2 emissions to regional final demand.
- **ALTERTAX**: Post-model generation of a global SAM to provide an updated benchmark, can be used in combination of G-RDEM to provide future benchmarks.
- **FABIO link**: FABIO is a MRIO for Agri-Food products (192 countries and 130 products) derived from various FAO data bases.
- **G-RDEM**: A module for generation of long-term baselines using (as a default) the gross domestic product (GDP) and population projection at single country level for Shared Socio-Economic Pathways (SSPs) 1-5 (IIASA, 2018).

In the current research the G-RDEM module of CGEBox is used to the highest extent, as it draws on a set of projections for the SSPs developed for the Intergovernmental Panel on Climate Change (IPCC). This is combined with the CO_2 and non-CO_2 modules, which allows to understand the impact of trade agreements, energy and climate policies on CO_2 and non-CO_2 emissions, as well as water use/pollution.

2.2.1 Coverage of SDG indicators in the model

While the CGEBox covers a wider variety of SDG indicators, the main use of this model within the project meant to cover exclusively environmental indicators. Thus, Table 1 shows the covered indicators and their representation in CGEBox. These indicators are either endogenously determined in the model or derived from the model outcome.

Table 1 Representation of SDG indicators in CGEBox

SDG indicator (from list of D1.2)	*Representation in CGEBox*
CO_2 emissions from agriculture (SDG Indicator 13.2.2: Total greenhouse gas emissions per year)	Linked. Based on GTAP CO2 emission module. Endogenous outcome based on historical emission data from the agricultural sector.

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SDG indicator (from list of D1.2)	*Representation in CGEBox*
CH_4 emissions from agriculture (SDG Indicator 13.2.2: Total greenhouse gas emissions per year)	Linked. Based on GTAP Non-CO2 emission module.
N_2O emissions from agriculture (SDG Indicator 13.2.2: Total greenhouse gas emissions per year)	Linked. Based on GTAP Non-CO2 emission module.
CO_2 emissions from fuel combustion	Linked. Based on GTAP-E module.
CO_2 emissions per unit of GDP	Derived.
CO_2 emissions per unit of manufacturing value added (9.4.1: CO2 emission per unit of value added)	Derived.

Source: own compilation from Deliverable D.1.2 of TRADE4SD (Jambor *et al.*, 2022) and CGEBox

The key advantage of CGEBox is capturing the global development paths for the next decades within the different International Institute for Applied Systems Analysis (IIASA) SSPs, which represent different approaches to world transformation. This allows to understand implications of modelled indicators along with the numerous development assumptions.

Limitations of CGEBox approach are the high sectoral and geographical aggregations (country level being the lowest), as well as exogenous emission coefficients.

2.2.2 Coverage of policy instrument related to SDG indicators in the model

The policies covered in CGEbox correspond well to selected SDG indicators. Table 2 gives an overview of the policies in CGEbox and their relationship to SDG targets and corresponding indicators. The focus lies on the reduction of emission from agricultural production.

Table 2 Covered policies and their link to SDG indicators

Policy instrument in CGEBox	*Market effect of policy instrument*	*Related SDG indicators*
Tariff lines	European Union (EU) full trade liberalization with countries with lower ratio of emission/value of production	Emissions from agriculture and transportation
Carbon tax	Taxation of emission-intensive products	Reducing emissions from agriculture by

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Policy instrument in CGEBox	*Market effect of policy instrument*	*Related SDG indicators*
		taxation of supply side
Selected instruments related to the European Green Deal	Shift in production towards less emission-intensive products	Reducing emissions from agriculture driven by changes in consumer preferences (demand side)

Source: own compilation from CGEBox model

2.2.3 Envisaged extension of the model by policy instruments and SDG indicators

Key aim is to provide arguments for new/better policies for trade considering environmental measures, such as tools of climate change mitigation and reduction of pollution (e.g. water). Table 3 provides an overview of possible extensions in AGMEMOD to represent and analyse polices and SDG indicators more accurately.

Table 3 Possible extension of CGEBox to account for more SDG indicators

SDG indicator (from list of D1.2)	*Possible implementation in CGEBox*	*Challenges*
Greenhouse gas (GHG) emissions from agriculture and food sector (SDG Indicator 13.2.2: Total greenhouse gas emissions per year)	Attributing GHG emissions to sectors and country groups.	Modelling particular trade agreements and defining direct and indirect links to changes in emissions.
Water use efficiency (SDG Indicator 6.4.1: Change in water-use efficiency over time; SDG Indicator 6.4.2: Level of water stress: freshwater withdrawal as a proportion of available freshwater resources)	Total water use by sectors in m^3 and changes in water use in relation to available freshwater resources	Water use will be estimation for water use efficiency. Changes in water use will be also used to estimate level of water stress. Challenges will be related to data availability and post-simulation calculations to estimate level of water stress.
Food Transport Emissions (SDG 13.2.2: Total greenhouse gas emissions per year)	Disaggregation of transportation sector	Data availability.

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SDG indicator (from list of D1.2)	*Possible implementation in CGEBox*	*Challenges*
Biodiversity (SDG 15)	Post-simulation calculation of Herfindahl index of sectoral specialisation.	Lack of regional data.

Source: own compilation

Strict limitation of greenhouse gasses, even though leading to positive climate change impact through SDG 13, could lead to decrease to supply of agricultural production and price growth, thus endangering other SDGs, such as SDG 2.

Trade policies in general do not aim at reducing emissions and impact on emissions depends of relative emission-intensity of the countries involved in the trade agreements. Agreements with low-emission countries will contribute to lower global emissions, while agreements with high-emission countries might contribute to an increase in emissions.

Food transport emissions are directly connected with the trade intensity, which is supported by the trade liberalization. In this regard the distance and transport energy efficiency play crucial roles, both of which are outside of the range of changes in agricultural sectors.

The resolution of data and possible results concerning the SDG indicators is at country and sectoral level, the sectoral division follows the GTAP classification.

The first two extensions are highly feasible for implementation, while the Food Transport Emissions is mainly related to transport due to international trade, and changes in the transport emissions and relocations of products within the countries cannot be traced. With the Biodiversity, it would be based on distribution of share of different products at the country level and it is likely not to include more detailed information at the regional level.

2.3 MAGNET

MAGNET is a computable general equilibrium model (Woltjer *et al.*, 2014). It is an extension of the GTAP model (Hertel, 1997) so the standard GTAP model and its database is the core of MAGNET. It covers all sectors of the economy (agriculture, manufacturing and services) and all regions and major countries in the world. The model is used especially for trade, biofuel, agricultural and other policy analyses as well as for long-term projections of the world economy. It has been developed at Wageningen Economic Research and is applied and further extended at Wageningen Economic Research, the Thünen Institute and the Joint Research Centre of the European Commission.

The MAGNET model is based on neo-classical microeconomic theory. In the most extended MAGNET version, production side is modelled using multilevel nested constant elasticity of substitution (CES) and Leontief production function. In the primary value-added nest, the substitution of different primary production factors (land, labour, capital and natural resources) and some intermediate production factors (e.g. energy, fertilizers, and animal feed components)

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is introduced. The CES nest is also introduced to consider substitution possibility between different intermediate input components, e.g. between energy sources. For the remaining intermediate inputs, fixed input-output coefficients are used.

On the consumption side, one household per region is distinguished. The household incomes are allocated to private and government consumption and savings using fixed budget shares. Private consumption demand for different commodities is explained through Constant Difference of Elasticities function. In the extended MAGNET version, income elasticities of consumption are decreasing function of purchasing power parity corrected real GDP per capita. Government allocates its expenditures across commodities according to fixed shares. The commodities consumed by firms, government and households are CES composites of domestic and imported commodities. Imported commodities are differentiated by region of origin using the Armington assumption (Armington, 1969). International transport is based on a Cobb-Douglas production function.

The GTAP database (Aguiar *et al.*, 2019) is the core database of the MAGNET. However, multiple satellite databases complement it (Woltjer *et al.*, 2014) due to the various extensions of MAGNET compared to GTAP. The various extensions in MAGNET are modelled in a modular way so that they can be switched on and off. This makes MAGNET flexible and ready to be applied to various research questions.

2.3.1 Coverage of SDG indicators in the model

MAGNET has already addressed the issue of including SDG indicators into the model (WEcR MAGNET team, 2017). MAGNET as a CGE model covering the whole economy is not only focusing on agriculture but also on the energy sector or the bioeconomy. Table 4 shows the indicators related to the total economy or agriculture only and their representation in MAGNET. These indicators are either endogenously determined in the model, exogenous to the model, or derived from model outcome. For a full list of indicators see Jambor *et al.* (2022).

Table 4 Representation of SDG indicators in MAGNET

SDG indicator (from list of D1.2)	*Representation in MAGNET*
Proportion of population below international poverty line	Derived from per capita income distributed by income class
Growth rates of household expenditure or income per capita	Endogenous model outcome
Ratio of land consumption rate to population growth rate	Ex-post calculation from endogenous land use change and exogenous population growth
Land, forest area	Exogenous in model with option to model forest area endogenous
Production and trade of forest products	Endogenous in model

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SDG indicator (from list of D1.2)	*Representation in MAGNET*
Developing countries' and least developed countries' share of global exports	Directly computable from model outcome per scenario
Average tariffs faced by developing countries, least developed countries and small island developing States	Directly computable from model outcome per scenario
Prevalence of undernourishment	Derived from food access indicators such as share of food expenditure in total income, food consumption and food consumption per capita, food prices
Productivity and income of small-scale food producers	Derived from food availability indicators such as domestic food production, trade in food, calories per capita per day, share of calories from cereals, protein intake per person from livestock, share of calories from fruit and vegetables
Agricultural export subsidies	Exogenous input as index of export subsidies on agricultural food products and average export subsidies on agricultural food products (ad valorem rate)
Real GDP growth (per capita)	Exogenous in baseline, endogenous in scenarios
Employment by sector/ in agriculture	Endogenous in model depending on exogenous population, technical progress, and endogenous labour movement
Trade: imports, exports, balance, share of GDP, share of domestic demand, performance, growth rates,	Endogenous in model
Production price, producer price index	Endogenous in model
Share of agriculture in GDP	Endogenous in model
Tariffs	Exogenous ad valorem rates to model per bilateral trade flow, (sub-)totals as endogenous model outcome
Material footprint	Derived as ex-post calculation per industry
Domestic material consumption	Derived as ex-post calculation per industry covered

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SDG indicator (from list of D1.2)	*Representation in MAGNET*
Proportion of tariff lines applied to imports from least developed countries and developing countries with zero-tariff	Derived as ESTAT Indicator from exogenous tariffs in MAGNET
Food loss and waste index	Extra module with green, grey and other waste per sector
Share of renewable energy in the energy mix	Renewable energy sectors modelled, share derivable
GHG emissions	Derived as ex-post calculation for emissions per unit of GDP/output, emissions per calorie
Total government revenue as a proportion of GDP by source	Endogenouse model outcome

Source: own compilation from Deliverable D.1.2 of TRADE4SD (Jambor *et al.*, 2022), WEcR MAGNET team (2017) and JRC (2022)

The main drawback of MAGNET with regard to the representation of SDG indicators is the relying on value-based flows instead of physical quantities which are often the basis for SDG indicators (Philippidis *et al.*, 2018). Consequently, the SDG indicators or unofficial but attributable indicators are primarily based on value flows, and only some use of physical units, such as land use in hectares or food consumption in calories (Philippidis *et al.*, 2018).

2.3.1 Envisaged extension of the model by policy instruments and SDG indicators

In the current application MAGNET is used to analyse the social dimension of sustainable development. Despite the work done in MAGNET regarding the representation of SDG indicators, sever extensions are foreseen.

A model-based analysis of social aspects of sustainability faces very significant challenges. As can be seen from the previous table, the indicators of the social aspects of sustainability already included in the MAGNET model represent a very broad and heterogeneous field. In TRADE4SD we want to expand the set of indicators covered. For this purpose, Table 5 gives a brief overview of the possible indicators of social sustainability, including an assessment of the possibility of a model-based coverage.

Table 5 Possible extension of MAGNET to account for more SDG indicators

SDG / Indicator	***Ability of cover in the model***	***Description***
Goal 1. End poverty in all its forms everywhere		
01_10	**?**	People at risk of poverty or social exclusion

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SDG / Indicator	***Ability of cover in the model***	***Description***
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture		
02_20	*	Agricultural factor income per annual work unit
Goal 3. Ensure healthy lives and promote well-being for all at all ages		
03_11	**?**	Healthy life years at birth
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all		
04_20	**?**	Tertiary educational attainment Y25-34
Goal 5. Achieve gender equality and empower all women and girls		
05_20	**?**	Gender pay gap in unadjusted form
Goal 6. Ensure availability and sustainable management of water and sanitation for all		
06_60	**?**	Water exploitation index, plus (WEI+)
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all		
07_10	*	Primary & final energy consumption
07_20	*	Final energy consumption in households per capita
07_50	*	Energy import dependency
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all		
08_10	*	Real GDP per capita
08_11	*	Investment share of GDP
08_30	*	Employment rate
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation		
09_10	**?**	Gross domestic expenditure on R&D
Goal 10. Reduce inequality within and among countries		
10_10	*	Purchasing power adjusted GDP per capita
10_41	**?**	Income quintile share ratio
10_50	**?**	Income share of the bottom 40 % of the population

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SDG / Indicator	***Ability of cover in the model***	***Description***
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable		
11_40		Road traffic deaths
Goal 12. Ensure sustainable consumption and production patterns		
12_50		Generation of waste excluding major mineral wastes
Goal 13. Take urgent action to combat climate change and its impacts		
13_10	*	Greenhouse gas emissions
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development		
14_40		Bathing sites with excellent water quality
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss		
15_10		Share of forest area
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels		
16_30	**?**	General government total expenditure on law courts
16_50		Corruption Perceptions Index
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development		
17_10	**?**	Official development assistance as share of gross national income
17_30	*	EU imports from developing countries
17_40	*	General government gross debt
17_50	**?**	Shares of environmental taxes in total tax revenues

Source: own compilation

As can be seen from the table, a model-based analysis of social aspects of sustainability faces very significant challenges. The field of different aspects is very heterogeneous and many indicators can only be derived indirectly from the different models. In addition to the selection and mapping of endogenous variables, disaggregation also plays a crucial role here in representing the different economic sectors and especially the different private households.

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Indeed, since both the CGEBox and the MAGNET model use the GTAP database, which has twelve agricultural (sub)sectors and five energy sectors, this is a possibility in these models of the WP3 modelling toolbox.

Also eleven indicators describing the social dimension of sustainability were regarded to be problematic (?) in terms of whether they could be properly represented in the WP3 modelling toolbar.

The remaining five Sustainable Development Indicators (SDIs) which were not marked neither by * nor by ?) are practically impossible to be represented in our WP3 modelling toolbox. However, all but one has nothing to do with socio-economic effects and income distribution. Only, the corruption index seems to be relevant for WP3, but to build its (forward and backward) linkages into our models would require a completely different framework. Although for Hungary a 5-sector dynamic CGE-model in which the inequality, the corruption and democracy index is properly represented, see Révész (2006), Révész and Takács (2011a) and Révész and Takács (2011b). However, it would be rather difficult and time-consuming to update this approach and it seems almost impossible to integrate it in a global model with multiple sectors.

Regarding the eleven SDIs marked by "?" we may observe concretely the following:

The 'water exploitation index' (06_60) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources. Therefore, its representation in the models depends on whether the water-supply industry is separated out (as it is in the GTAP database with the sector code 'wtr') and whether the models include (estimate or use data for) the 'long-term average freshwater resources' as a separate category of the production factors or natural resources. In any case, to highlight the problems of endogenizing the natural resources we may quote from Corong *et al.* (2017):'Lacking data on the development of natural resources, we use a fraction of the change in capital to compute the change in the natural resource endowment'.

The 'Gross domestic expenditure on R&D' (09_10) is difficult to be represented in such disaggregated models like the CGEBox or MAGNET. This indicator has to be computed endogenously from the sector specific model categories and from a detailed representation of the government transfers in the model's income distribution block, while such details are neither available in the respective data base nor covered in the models' equations. In addition, the supposed result of the R&D, i.e. the technological progress has not been properly represented in the global multisectoral models. Most CGE models assume that technological development is the same between sectors or industries, which is not in line with empirical evidence. The standard GTAP technical progress is implemented as either in terms of Hicks-neutral technical change or as a factor-augmenting technical change which represent technical change without sectoral differentiations (Corong *et al.*, 2017). Technological change can take various forms, such as Hicks-neutral technological change (measured by total factor productivity) that is identical for all production factors, or it can be non Hicks-neutral and have different weights for different production factors. It is also possible to have for intermediate input saving

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technological change. In MAGNET, factor augmenting technical change can be set for all input types: labour, capital, land, natural resources and intermediates. MAGNET also includes several pieces of code that explicitly model differences in technological change across sectors for the baseline projection. At the moment, technological change can only be set for three aggregated sectors: agriculture, manufacturing and services (Woltjer *et al.*, 2014).

As far as disaggregated government budget data availability is concerned, similar can be said about the 'General government total expenditure on law courts' (16_30) and 'Official development assistance as share of gross national income' (17_10). Law courts are not separated out of the public administration sector and the models do not portray the foreign balance of payment in such a detail that development assistance in terms of aid, loan, and or a membership fee in international organizations may be visible. Even if data were available for these categories it remains unclear how they can be presented in the modelling toolbox of WP3. In addition, the standard GTAP database does not distinguish important income flows such as foreign labour remittances, foreign capital remittances or foreign aid flows. However, in the cases of foreign remittances and capital payments and foreign aid, the MYGTAP application augments (disaggregates) household income for all regions for these values automatically based on international estimates of these values, see Minor and Walmsley (2013), McDonald and Sonmez (2004), and Walmsley and Minor (2013).

The representation of the 'Shares of environmental taxes in total tax revenues' (17_50) also depends on the exact definition of the 'environmental taxes' (which may range from environmental load fees to various resource taxes and excise tax on motor fuel) and whether the tax system is sufficiently detailed and elaborated in the given models. Here the modelling of environmental taxes should be explicit, because their mechanisms are complex and intricate, with many exemptions and 'grandfathering' phenomena.

The remaining 'problematic' SDIs are related to the existence of multiple households (i.e. the disaggregation of the household sector) in the models. These indicators are the following:

- 'People at risk of poverty or social exclusion' (01_10)
- 'Healthy life years at birth' (03_11)
- 'Tertiary educational attainment' (04_20)
- 'Gender pay gap in unadjusted form' (05_20)
- 'Income quintile share ratio' (10_41)
- 'Income share of the bottom 40 % of the population' (10_50)

Although education is one of the sectors of the GTAP database, it is not split into primary, secondary and tertiary education subsectors. Therefore, the 'Tertiary educational attainment' can be endogenized only by measuring the government spending on this subsector, which in turn requires again the break-down of the government transfers so that such items may be visible in the given model.

Similar can be said about the 'Healthy life years at birth' indicator. Health depends not only on the government spending on the health care system, but also on the life-style of the population, on the working conditions, on the corruption level (especially in those countries where the

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medical staff may be bribed by the patients) and many other factors, e.g. the COVID-19 pandemic which cannot be endogenized in such models as the MAGNET or CGEBox.

Since the labour force is not split by gender in the model databases, the ‘Gender pay gap’ can be estimated in our models only from some proxies, like the general pay gap (earnings inequality). However, the change in some components of the gender pay gap may be estimated from the wage levels of the individual industries, the sectoral wage indices, and the percentage share of women in the employees of the sectors. In any case, this indicator may not be the main responsibility of WP3 to address this issue.

As far as the ‘People at risk of poverty or social exclusion’, ‘Income quintile share ratio’ and ‘Income share of the bottom 40 % of the population’ indicators are concerned, their representation of the model depends on the break-down of the household sector by income level. Since the household sector has to be broken-down by other socio-economic categories, one has to consider how many and which groups may be defined in the model by combining these attributes, i.e. which subsets of the Descartian-product of the attributes will form separate socio-economic groups of the household sector.

In addition to mapping the various indicators of social sustainability, it is particularly important to map private households disaggregated in the models. Only on the basis of a differentiated representation of private households is it possible to adequately analyse the distributional effects of trade and policies. Here, the MAGNET model already offers options in its modular structure, which will be further developed in TRADE4SD. The detailed description of the model extension will be presented in While this report only gives an overview of the selection of SDIs, the detailed description of the model extensions will be given in the following deliverables.

2.4 AGLINK-COSIMO

AGLINK-COSIMO is an economic model that analyses supply and demand of world agriculture (OECD, 2015). It is managed by the Secretariats of the Organisation for Economic Co-operation and Development (OECD) and Food and Agriculture Organization of the United Nations (FAO), and used to generate the OECD-FAO Agricultural Outlook (OECD and FAO, 2021) and policy scenario analysis.

AGLINK-COSIMO is a recursive-dynamic, partial equilibrium (PE) model used to simulate developments of annual market balances and prices for the main agricultural commodities produced, consumed and traded worldwide. The AGLINK-COSIMO country and regional modules covering the whole world, and projections are developed and maintained by the OECD and FAO Secretariats in conjunction with country experts and national administrations. Several key factors or assumptions are as follows:

- World markets for agricultural commodities are competitive, with buyers and sellers acting as price takers. Market prices are determined through a global or regional equilibrium in supply and demand.

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- Domestically produced and traded commodities are viewed to be homogeneous and thus perfect substitutes by buyers and sellers. In particular, importers do not distinguish commodities by country of origin as AGLINK-COSIMO is not a spatial model. Imports and exports are nevertheless determined separately. This assumption will affect the results of analysis in which trade is a major driver.
- AGLINK-COSIMO is a PE model for the main agricultural commodities. Non-agricultural markets are not modelled and are treated exogenously to the model. As non-agricultural markets are exogenous, hypotheses concerning the paths of key macroeconomic variables are predetermined with no accounting of feedback from developments in agricultural markets to the economy as a whole.
- AGLINK-COSIMO is recursive-dynamic. Thus, each year is modelled over the projection period and depends on the outcome of previous years. AGLINK-COSIMO models ten years into the future.

2.4.1 Coverage of SDG indicators in the model

SDG indicators are not directly covered in AGLINK-COSIMO. Nonetheless, the projections can be used together with additional inputs, to indirectly derive SDG indicators. Table 6 summarizes the main SDGs which could be derived, with additional input, from the AGLINK-COSIMO projections.

Table 6 Representation of SDG indicators in AGLINK-COSIMO

SDG indicator (from list of D1.2)	*Representation in AGLINK-COSIMO*
*Food Loss Index (*FLI)	Estimation of the FLI by indexing historical figures to the food availability projections.
13.2.2 Total greenhouse gas emissions per year (only Agriculture)	Estimation of the direct GHG emissions from Agriculture by indexing historical figures to the production projections
Fish stocks sustainability	Estimation by indexing historical figures to the fisheries projections
Value added of sustainable fisheries	Estimation by indexing historical figures to the fisheries projections
Prevalence of undernourishment	Estimation of the prevalence of undernourishment
Food Price Volatility	Estimation bound to the stochastics model
6.4.1 Change in water-use efficiency over time	Estimation by indexing the water efficiency to the development of crops and livestock production projections from the model

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SDG indicator (from list of D1.2)	*Representation in AGLINK-COSIMO*
7.2 By 2030, increase substantially the share of renewable energy in the global energy mix (only biofuels)	Limited only to biofuels
9.4.1 CO_2 emission per unit of value added	Limited to commodities covered by the model
Area harvested of crops and livestock products	Area (hectares) of harvested crops and livestock products
Yield of crops and livestock products	Yield of harvested crops and livestock products
Production quantity of crops and livestock products	Amount (tonnes) of harvested crops and livestock products
Total exports by country	The products exported by countries in terms of quantity or price
Total imports by country	The products imported by countries in terms of quantity or price
Total exports to GDP	Total exports in GDP show the dependence of domestic producers on foreign markets (%)
Total trade to GDP	Total trade (the sum of exports and imports) as a share of GDP measures the dependence on foreign markets and intermediate inputs and, on the other hand, the importance of international trade in the country
Domestic final demand met by total imports	Indicator measures the share of total domestic final demand (the difference between GDP and net exports) met by imports. Sometimes it is referred to as an import penetration rate
Production price	The price paid to a company or person for the goods they produce or the food that they grow
*Producer Price Index (*PPI*)*	The PPI measures the average change over time in the selling prices received by domestic producers for their output

Source: own compilation from Deliverable D.1.2 of TRADE4SD (Jambor *et al.*, 2022) and AGLINK-COSIMO

2.4.2 Coverage of policy instrument related to SDG indicators in the model

Table 7 summarises policy instruments covered in AGLINK-COSIMO related to the SDG indicators in the model.

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Table 7 Covered policies and their link to SDG indicators in AGLINK-COSIMO

Policy instrument in AGLINK-COSIMO	*Market effect of policy instrument*	*Related SDG indicators*
Import Tariff	Reduces trade	SDG2 No Hunger, Farm Income
Import Quotas	Reduces trade beyond a threshold	SDG2 No Hunger, Farm Income
Biofuels Mandates	Binds biofuels´ consumption to fossil fuels	SDG7 Affordable and Clean Energy
Biofuels Tax credits	Favors biofuels consumption against fossil fuels	SDG7 Affordable and Clean Energy

Source: own compilation from AGLINK-COSIMO model

2.4.3 Envisaged extension of the model by policy instruments and SDG indicators

Envisaged extensions of the model related to policy instruments and SDG indicators are listed in Table 8. These extensions, however, can be realised only for the commodities or commodity aggregations as well as for the regions/countries covered in the model.

Table 8 Possible extension of AGLINK-COSIMO to account for more SDG indicators

SDG indicator (from list of D1.2)	*Possible implementation in AGLINK-COSIMO*	*Challenges*
Self Sufficiency Ratio	Calculated by commodity and/or groups of commodities	Limited to commodities covered in the model
FAO Price Index	Calculated following FAO's methodology	
Import bill	Calculated by commodity and/or groups of commodities	Limited to commodities covered in the model
Food expenditure	Calculated by commodity and/or groups of commodities	Limited to commodities covered in the model

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SDG indicator (from list of D1.2)	*Possible implementation in AGLINK-COSIMO*	*Challenges*
Production decomposition	Calculated by country/region and commodity/group of commodities	Limited to the commodity aggregation level in the model, i.e. provided for other coarse grains and not by individual crops such as barley, oats, sorghum, etc..

Source: own compilation

2.5 AGMEMOD

AGMEMOD is a dynamic, multi-country, multi-market, econometrically estimated, PE model (Chantreuil, Hanrahan and van Leeuwen, 2012). It covers the main agricultural and its processing sectors for all EU Member States and some EU neighbours.

The model is regularly used for outlook projections at the EU level and national level (e.g., in Haß *et al.* (2020) for Germany). Since 2015, AGMEMOD contributed to each Medium term outlook of the European commission (EC, 2021). Additional, policy analysis with the focus on the EU Common Agricultural Policy (CAP) are conducted (Haß, 2021).

The system has been operational since 2000. It is currently maintained, extended and regularly updated by the AGMEMOD consortium with Wageningen Economic Research and the Thünen-Institute at its core. It includes the expertise of an extensive network of economists collaborating across the EU.

AGMEMOD requires long time series to estimate its parameters. Each country model is based on a database of annual time series, covering, when possible, a period from 1973 to the latest available year. The database is similar across countries and includes balance sheets for all primary agricultural commodities and most food processing commodities, generally including prices, production, imports and exports, opening and ending stocks as well as food, feed and other consumption. Data is collected from various sources such as national, European and international statistics. Data harmonization, manipulation, and adjustments are required to build a consistent database across countries and commodities.

Each country model uses a common country model templates with predefined relationships between the variables. The specific equations can differ in functional forms and parameter values to reflect the specific situation of the agricultural sectors in the individual countries with differences in agricultural systems, policy instruments or data availability according to country individual requirements. The country models are linked through price transfers with each other and integrated into a general model, capturing all represented countries as well as a stylist representation of the rest of the world. Trade is represented by commodity as total exports and

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total imports of a country. Additionally, exports or imports normally used as closing variable for the market balance in the model.

Projections and scenario analysis are possible on a yearly basis up to 2040. These projections are mainly driven by world market prices for represented products, agricultural policies and macroeconomic variables such as GDP and population.

2.5.1 Coverage of SDG indicators in the model

The SDG indicators covered by the current version of AGMEMOD are exclusively economic indicators. Table 9 shows the covered indicators and their representation in AGMEMOD. These indicators are either endogenously determined in the model or exogenous to the model.

Table 9 Representation of SDG indicators in AGMEMOD

SDG indicator (from list of D1.2)	*Representation in AGMEMOD*
Area harvested of crops and livestock products	Endogenous outcome based on historical trends, policies, price relationships, competition between products
Yield of crops and livestock products	Endogenous outcome based on historical trends, policies, price relationships
Production quantity of crops and livestock products	Area harvested/ Animal numbers * yield
Exports by country	Endogenous outcome based on price relations, markets situation, often amount not domestically consumed
Imports by country	Endogenous outcome based on price relations, trade policies, markets situation
Production price	Endogenous outcome based on world market prices, agricultural policies, market situation
Agricultural market and trade policies	Exogenous, variations in scenarios show impact on markets, Coverage: Coupled and decoupled payments, intervention price, tariff-rate quotas (TRQs), tariffs, EFA/ fallow land requirements

Source: own compilation from Deliverable D.1.2 of TRADE4SD (Jambor *et al.*, 2022) and AGMEMOD

AGMEMOD covers total land use of a country with a focus on agricultural production. Changes in total agricultural area is an outcome of historical trends (e.g., to mimic area lost due to building of infrastructure and settlements) and changes in policies (such as decoupled payments per hectare, requirements for fallow land). Agricultural area is represented in a nested structure with different sub groups. For example, wheat is part of the sub group grains which in turn is

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part of the sub group crops which in turn is part of the sub group arable land which is part of total agricultural area. In each nest, the gross margin which is representing a proxy for competition between the different sub groups determines the amount of area allocated to a specific sub group.

Yields are projected depending on a historical trend and own expected prices. If available, proxies for input costs such as a cost index or energy prices can also determine yields. Additionally, policies can be reflected in the yield equation. For example, the effect of the ban of neonicotinoids for rapeseed has been estimated as a downward shift in yields.

The production quantities for crops are the area harvested multiplied by the yield. In the case of livestock, the production quantities are the animal numbers multiplied by yields. Consequently, any policies effecting production are implemented in AGMEMOD either via yields, area harvested, or animal numbers depending what the policy directly impacts.

Exports and imports are represented by totals, that is no distinction between bilateral trade of countries nor EU intra or extra trade is done. The projected trade flows depend on price relationships between domestic and world market prices as well as production and consumption. Either exports or imports are represented as an accounting equation to close the market balance.

For EU countries, the producer prices in AGMEMOD are modelled in two ways. One country per commodity is selected as key country and a so-called key price is estimated. This key price depends on the development of the exogenously given world market prices, EU wide policies, and the EU wide market situation. All other EU countries estimate their prices dependent on the price key price, their own self-sufficiency, and if applicable national individual policies.

In AGMEMOD, several agricultural and trade policies are explicitly modelled. The database is a source of historical development for these specific policies (details in next section). The policies are given exogenously to AGMEMOD and can be varied to conduct scenario analysis to quantify the impact of them on agricultural markets. Represented SDG indicators in form of policies are agricultural export subsidies (Indicator 2.b.2), average tariffs (Indicator 17.12.1) but not distinguished between origins, and a modified form of producer support estimate (Indicator 2.b.1).

AGMEMOD lacks the coverage of environmental and social indicators. First attempts to include some of these aspects have been done by linking AGMEMOD with the environmental model MITERRA (Gonzalez-Martinez *et al.*, 2021) and introducing a farm income module in AGMEMOD.

2.5.2 Coverage of policy instrument related to SDG indicators in the model

The policies covered in AGMEMOD only partially correspond to SDG indicators. Nevertheless, several of the policies influence the indicators mentioned above as well as other indicators. Table 10 gives an overview of the policies in AGMEMOD and their relationship to SDG targets and corresponding indicators. All of these policies influence the markets directly.

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In AGMEMOD, fallow land is modelled as a sub group of area or a share in agricultural area. Policies such as the ecological focus areas (EFA) as part of the Greening in the CAP of the EU 2014-2020 required to have a specific amount of set-aside area which is considered in AGMEMDO. The minimum amount of fallow land reduces agricultural area and, hence, production in AGMEMOD. The aim of the EFA policies are to reduce negative impacts from agriculture on the environment. Consequently, it contributes to the area of biodiversity of the SDG targets.

Table 10 Covered policies and their link to SDG indicators in AGMEMOD

Policy instrument	*Effect in model*	*Related SDG indicators*
Fallow land	Reduces agricultural area	Agricultural market and trade policies, Biodiversity*
Greening: EFA areas	Shift in area of protein crops, soybeans, fallow land to fulfil requirements	Biodiversity*
Intervention prices	Minimum domestic price, Level in EU reduced so that often not applicable anymore	Agricultural market and trade policies
Coupled direct payments	Commodity specific payments attached to output, heads, or area	Producer support estimates
Decoupled direct payments	Per hectare payments independent of production	Producer support estimates
Tariffs	Part of price and/or import function	Trade policies
Tariff rate quotas	Part of or import function	Trade policies
Biofuel policy	Crop-based feedstock requirements for set targets	Renewable energy share in the total final energy consumption

Note: *contributes to increase biodiversity, related qualitative indicator is „Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020"
Source: own compilation from AGMEMOD database

The EFA requirements can also be fulfilled by planting nitrogen-fixing crops such as legumes. The observed shift towards more soybean and protein production in the EU is partially attributed to that policy.

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In the EU, intervention prices for several products exist which ensure a minimum price. Historically, these have been reduced so that they are mostly only applicable temporary in case of low world market prices.

For several products, coupled direct payments exist in the EU. These payments are voluntary and country specific. They mostly apply to the ruminant livestock, protein, and sugar sectors.

The largest support to producers in the EU is given via decoupled payments. These decoupled payments are a per hectare payment with varying amounts between member states and over time. They are called decoupled because no specific production on the area is required to receive these payments.

Import tariffs and tariff-rate-quotas are also included in AGMEMOD. However, these tariffs and tariff-rate-quotas are strongly simplified as AGMEMOD only considers total exports and imports. However, these policies are often bilateral.

AGMEMOD includes the biofuel policy of the EU only in the form of exogenously given feedstock requirements for crop-based feedstocks. Consequently, substitution effects in the future are not modelled but exogenously given.

Besides the policies in Table 10, export subsidies, milk and sugar production quotas can be modelled with AGMEMOD but have been abolished in the EU. Hence, they are not modelled at the moment but could be reintroduced for scenario analysis. Additionally, some specific national policies are included in AGMEMOD such as biogas policies in Germany via a required amount of area attributed to feedstock production for biogas. For non-EU countries the individual national policies are covered and can include besides policies mentioned above also export taxes and input subsidies.

2.5.3 Envisaged extension of the model

The AGMEMOD model is well suited to analyses agricultural policies with a focus on economic impacts. Building upon this strength, AGMEMOD should be extend in three ways. First, improve the representation of trade and the accompanying policies. Second, model the new CAP policies which will be applicable as of 1st January 2023. Third, link the model outcome to additional SDG indicators especially to environmental and social indictors.

2.5.3.1 Envisaged change trade representation in AGMEMOD

In AGMEMOD, the total values of exports and imports are considered without distinction between bilateral trade flows. To project the role of trade policies in achieving sustainable development goals, AGMEMOD will be extended to model trade policies and agreements. This will allow the model to assess the role of trade in achieveing the SDGs by taking both the trade policies and the SDG goals into consideration.

Trade can be modelled using different approaches, the net trade model and the spatial trade model. In the net-trade models, trade is calculated as the difference between the aggregate value of exports and imports. Therefore, a country is classified as self-sufficient, an importer or an exporter of a certain product. The other way to model trade, is the spatial trade models, which

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allow for depiction of bilateral trade flows. Hence, countries can be exporters and importers of the same product at the same time.

The net trade model is the most applied approach to present trade in PE models, e.g., in IMPACT (Robinson *et al.*, 2015), AGLINK-COSIMO, and AGMEMOD. However, it is not able to represent bilateral trade flows and bilateral trade agreements. Therefore, the agriculture PE models face a limitation with the increasing number of bilateral trade agreements.

Armington (1969) introduced into international trade theory the fundamental assumption that products traded internationally are imperfect substitutes for each other, e.g., French machinery and Japanese machinery are two different products in the model and form a group of products in the consumer's utility function. The Armington model specified only the demand side of the model, while the supply side was the standard Neoclassical specification. The Armington approach is the most adopted approach in the CGE models and in some PE models such as CAPRI (Britz and Witzke, 2014).

However, the Armington model is based on the differentiation of the products according to their country of origin, the post-Armington literature distinguishes between horizontal differentiation (different varieties of a product) and vertical differentiation (different qualities of a product). The Armington model altered the proprieties of the traditional trade model in a way that countries have no comparative advantage and gain from product specialization trade. Additionally, by conidering the disjoint of the set of products produced by different countries, there is no price advantage to producing one product (Lloyd and Zhang, 2006).

The study of Nolte (2008) applied Spatial Price Equilibrium to cover 104 sugar producing and 90 sugar consuming regions, accounting for trade policies, bilateral trade agreements and bilateral transportation costs. The Spartial Price Equilibrium approach combines the assumption of homogeneous goods and the explicit depiction of bilateral trade flows. This approach allows a broad country and policy coverage, including a multitude of preferential and regional trade arrangements (Nolte, 2008).

The GLOBIOM model endogenously computes bilateral net trade flows through the minimization of the total cost of trading. It relies on the homogeneous good assumption where price difference between two regions is explained by transportation costs. Therefore, in this framework, the trade will occuer unidirectional between regions that have different prices by more than the interregional cost of transporting goods, and the price difference will be driven down to the transport cost. This allows trade patterns to be determined through initial trade flows, the evolution of relative costs of production between regions, and the trading costs (Havlík *et al.*, 2018).

The AGMEMOD model will be extended to model trade of the EU with other regions or countries bilaterally. For considering the trade policy, AGMEMOD will use quotas, TRQs, taxes and tariffs to calculate the export and import prices and will take the consumer and producer policies into consideration.

Further, AGMEMOD will consider transport cost, the distance between two countries of both trading partners when modeling trade. This allows the model to present the bilateral trade agreements between regions. Consequently, AGMEMODs trade modelling approach will be

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modified to include part of net trade theory with a presentation of transport cost as applied in GLOBIOM and elements of Spatial Price Equilibrium theory.

2.5.3.2 Envisaged extension of policy instruments and SDG indicators

Agricultural policies of the EU focus more and more on environmental aspects. These policies also impact agricultural markets and should be considered in an economic model, while some social aspects can be derived from the model outcome. Table 11 provides an overview of possible extensions in AGMEMOD to represent and analyse polices and SDG indicators more accurately.

Domestic final demand met by imports can be calculated in AGMEMOD per commodity or group of commodities, e.g., cereals. However, an aggregation to total demand met by imports is not possible. Nevertheless, a change in the derived share shows the development of the indicator over time and conclusion can be drawn from it. Similarly, a producer price index per agricultural commodity can be derived for each country.

Investments in agriculture are already represented in AGMEMOD by money transfer based on the CAP. The effect of investments on productivity can be modelled if the relationship between changes in investments and productivity (preferably per commodity) is known. This knowledge can be gained by a literature review or own research outside of the AGMEMOD work.

The agricultural market and trade policies require an update in AGMEMOD. The new policies of the CAP as being implemented as of 2023 will be modelled in AGMEMOD. These include new total budget, new voluntary coupled support, and fallow land. Their contribution of the new CAP to achieving SDG targets is currently questioned (Matthews, 2020). For details see also Huan-Niemi *et al.* (2022). Nevertheless, it is seen as important to include them in the analysis to be able to show the lack of contribution of these policies.

Additionally, policy options to achieve the Green Deal, Farm to Fork and Biodiversity strategy targets will be introduced. These are more in line to achieve especially environmental SDG targets and contribute to several environmental SDG indicators. These strategies focus on environmental restrictions which might most probably result in reduced production, i.e., required buffer stripes, reduced use of fertilizer and crop protection, reduced use of antibiotics. Trade will be modelled in more detail and non-tariff barriers representing specific environmental or social sustainability criteria can be added.

The SDG indicator "Proportion of agricultural area under productive and sustainable agriculture" is interpreted in the EU as share of organic area in total agricultural area. As this indicator is not directly compatible with the global indicator because sustainable production does not necessarily imply organic production only, we will not model it in AGMEMOD. Additionally, in order to model organic agricultural production in AGMEMOD would require to split all sectors into convention and organic production which due to data and time constraints is not feasible to be implemented.

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Table 11 Possible extension of AGMEMOD to account for more SDG indicators

SDG indicator (from list of D1.2)	*Possible implementation in AGMEMOD*	*Challenges*
Domestic final demand met by total imports	Derive from model outcome per sector, ex-post calculation	
Producer Price Index	Derive from producer prices	
Investments in agriculture	Change in productivity, exogenous factor affecting yields	Detailed data, specification of link to product specific yield development
Agricultural market and trade policies	Market relevant polices from the new CAP, update and extensions	Introduction of new policy options in system
	Inclusion of targets from the Green Deal, Farm to Fork and Biodiversity strategy through market relevant policies or external market shocks	Specification of policy instruments (if not given), determination of shocks
	Trade policies with sustainability requirements in form of non-tariff barriers	Change representation of trade to partially bilateral trade representation, quantifying and summing up non-tariff barriers
Proportion of agricultural area under productive and sustainable agriculture	Organic agriculture as separate sectors	lack of data and time constraint to split sectors between conventional and organic
Greenhouse gas emissions per year (only Agriculture)	Attributing GHG emissions to sectors and ex-post calculations	Data and mapping to AGMEMOD coverage, only one production system per product: reductions due to change in production system not possible
Food loss and waste index	Extend model by food loss and waste categories in market balance, model changes exogenously or through specific (new) policies	Data coverage and data mapping, sectoral breakdown, policy instrument modelling

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Source: own compilation

The SDG indicator of GHG emissions is an important one as it condenses many climate policies into one measure. The GHG emissions from the agriculture sector are still unaddressed by AGMEMOD. For this purpose, the AGMEMOD will be extended to include the greenhouse gas emissions for the agriculture sector, which will contribute to SDG 13 on climate action. The data will be extracted from the Eurostat database, which provides greenhouse gas emissions by source sector measured by thousand tons annually between 1990 and 2019. The greenhouse gas emissions from agriculture are CO_2, N_2O in CO_2 equivalent, CH_4 in CO_2 equivalent, HFC in CO_2 equivalent, PFC in CO_2 equivalent, SF6 in CO_2 equivalent, NF_3 in CO_2 equivalent. Consequently, GHG emissions will be attributed to each commodity produced in form of an ex-post calculation.

The two sub indicators of food waste index and food loss index are also important to consider. However, AGMEMOD does only include food loss in a rough form. Food waste is not separately modelled but included in the different domestic use categories. Data per EU member state is currently not yet available and difficulties in attaching them to one agricultural commodity are already know. Consequently, the inclusion of this indicator needs to be postponed to a later time if more data and knowledge about the amounts wasted is available.

Hence, the analysis with AGMEMOD will focus on the SDG indicators related to GHG emissions as well as agricultural and trade policies. For the latter, special attention is laid on the new CAP as well as the targets set out in the Green Deal, Farm to Fork and Biodiversity Strategy of the EU. Additionally, the reformulation of the trade specification in AGMEMOD will allow to model leakage effects with respect to global production shifts as a result of changes in EU production.

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3 Conclusion

The models in the TRADE4SD toolbox already cover several SDG indicators. However, for the envisaged analysis several extensions are required. The two CGE models will be applied for analysis with respect to environmental aspects (CGEBox) and social aspects (MAGNET). AGLINK-COSIMO and AGMEMOD, the two PE models, traditionally focus on economic aspects of the agricultural sector. They are or will be expanded to include more environmental and social aspects in the way that these can be derived or quantified in an ex-post manner after model simulations.

With the extension of the models, the models are fit to conduct scenario analysis later in the project. Thereby, each model will focus on scenarios with regard to their strength. CGEBox will concentrate on scenarios concerning GHG emission reduction by specific trade agreements, energy and climate policies. Additionally, water pollution will be addressed. MAGNET will focus on analysing impact on agricultural households in Ghana by varying trade and social sustainability policies. The PE models will explicitly address TRQs and impacts of trade and sustainability policies on agricultural markets and value changes in specific countries. AGLINK-COSIMO will focus on scenarios for Ghana and Vietnam, while AGMEMOD will concentrate on simulation for the EU member state countries.

As already described in this report, overlaps are to be expected in the four economic models used in TRADE4SD. However, these cross-cutting issues should be a strength of our analysis. In the presentation of the results of the different scenario analyses, they will help to clarify and make transparent the interrelationships, but also the possible conflicts in the achievement of the goals of the different aspects of sustainability.

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