Food and Agriculture Organization of the United Nations

Long-term scenario building for food and agriculture: A global overall model for FAO.

Brainstorming workshop. Friday, 19 February 2016

Global Perspectives Studies (GPS) Team, FAO UN – Rome

Contributions, findings and ways forward

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1 Introduction

This report, prepared by the Global Perspectives Studies (GPS) team of FAO, contains the contributions of the participants in the workshop "*Long-term scenario building for food and agriculture: A global overall model for FAO*", held at FAO headquarters on 19 February 2016. It also outlines selected follow up actions for the GPS team in the preparation of the new FAO forward-looking exercise: World Food and Agriculture towards 2050-80 (FAT2080). More specifically, Section 2 provides some background information on the previous activities of the GPS team while Sections 3, 4 and 5 present the contributions of the various workshop participants to each thematic session. Section 6 outlines the follow up actions that the GPS team should undertake to implement the workshop findings. The workshop agenda and the list of participants follow in the annex. The presentations of the contributors to the various sessions are available upon request from the Global Perspectives Studies team of FAO (global-perspectives@fao.org) or can be downloaded from: http://www.fao.org/economic/esa/esa-activities/perspectives/en/ .

2 Background

FAO has been carrying out global long-term analyses since the 1960s, with the goal of offering a strategic policy perspective and of contributing to defining FAO policy priorities to responses to external emerging challenges. The widely used series of reports titled "World Agriculture towards 20XX" (AT20xx) started with 2000 as the first end-year of the projection period. Projections were updated to 2050 in the latest revision (Alexandratos and Bruinsma, 2012). These studies relied on the broad expertise within FAO, which informed core long-term projections on demand, supply and resource use of agricultural and food products. More recently corporate reports on key issues have been prepared, such as the report on "*Achieving Zero Hunger - The critical role of investments in social protection and agriculture*" (FAO, IFAD and WFP, 2015).

Since 2012 and following the recommendations of the internal evaluation of the Global Perspectives work of FAO, the GPS Team has included scenario analysis as part of the methodology. For this purpose, the FAO "Global Agriculture Perspectives System – Partial Equilibrium" (GAPS-PE) was developed. GAPS-PE is a partial equilibrium model covering currently 182 countries and 35 agricultural and food commodities, used to derive long-term projections of global demand and supply of agricultural products. GAPS-PE facilitates detailed analysis of crop and livestock production across different production systems per country.

Given FAO's broader mandates regarding food security, nutrition and sustainable agriculture, a more comprehensive framework is needed, which also considers long-term social and economy-wide development processes, demographic trends, shifts in dietary patterns and environmental constraints. The key factors influencing entitlements to food and other basic needs, as well as the use of and limits to natural resources will need to be taken into account to generate plausible projections and scenarios for food security over the long run. Economy-wide aspects to be taken on board include sectoral patterns of production and employment (structural change), trends on labor and other factor markets, income generation and distribution, savings and capital accumulation processes, financing of investment

(domestic and foreign), and availability of quality of land and other agriculture-related natural resources and capital stock.

FAO is considering developing a Global Economic Model Framework for Sustainable Agriculture and Food Security (GEM-SAF), which is dynamic and constructed for conducting long-term scenario analysis and simulations. The framework may have a general equilibrium model at its core, linked to other modeling frameworks, including FAO's GAPS-PE model. Such linkages may include the assessment of agricultural factor-specific productivity trends given physical and environmental boundaries to agriculture and food production. The modeling framework should support the scenario analysis in preparation of the FAO report: "*World Food and Agriculture towards 2050-80*" report and updates thereof. To this end, it should help to address key questions related to the development of global and country-specific socio-economic systems in the long run.

The FAO brainstorming workshop "*Long-term scenario building for food and agriculture: A global overall model for FAO*" was organized with three objectives in mind:

1. To identify the key features a model should have so as to be adequate for long-term scenario analysis and suitable for addressing key development questions for the FAO GPS work.
2. To identify approaches to implement such model features and to determine the extent to which they are already embedded in existing models.
3. To trace a step-wise pathway to endow the FAO GPS team with a suitable and operational GEM-SAF with desirable features.

An additional goal of the workshop was to create internal and external awareness on the recent, ongoing and planned work of FAO's GPS team.[1]

The workshop had the form of an expert consultation, where participants from different organizations involved in forward-looking exercises contributed to define the contours of the modeling framework to underpin coherent long-term scenario analyses.

3 Session 1: Looking into the future: key questions for the next FAO forward-looking exercise

After a welcome address and the key opening remarks, Mr Kostas Stamoulis, Assistant Director General *ad-interim* of FAO's Economic and Social Development (ES) Department, provided an overview of how long-term projections have been carried out in the past and outlined the need to focus not only on agricultural commodity markets per se but, rather, on how to ensure food security in a sustainable way given the dynamics of global population and income and the challenges related to climate change.

Subsequently, Mr Rob Vos, the Director of FAO's Agricultural Development Economics Division (ESA) highlighted the goals and the expectations of the workshop, in the light of the challenges related to modeling future scenarios, to be faced by the Global Perspectives Studies team in the near future. He

[1] The workshop's concept note can be retrieved from: http://www.fao.org/economic/esa/esa-activities/perspectives/en/

pointed out that an economy-wide model is needed to support scenario analysis along all the dimensions of Food and Nutrition Security (FNS).

Mr Lorenzo Giovanni Bellù, Team Leader of the GPS team, elaborated in his presentation more on the topics that need to be considered in the FAT2080 report and how they are addressed in narratives of scenarios that are available in the literature. He set the framework for the whole workshop and highlighted the key questions that were then put at the basis of the presentations and discussions held in the second session of the workshop. The key questions were:

1. **Population growth, migration**. How to take into account population growth in FNS projections? How to take into account related pressure on natural resources? To what extent intra and cross-country migrations would affect food production, consumption and trade? How is urbanization going to change consumption patterns? What do these impacts imply, other things being equal, for global food security by 2030 and 2080? How sensitive are these outcomes to assumptions about population trends?
2. **Limits to natural resources**. Are FNS achievements in danger, considering the limited natural resources available? How to consider future yield increases as compared to land expansion? Where would competing land use become most under stress? To what extent and with what trajectory will current trends in land erosion and degradation of agriculture-related natural resources affect agricultural productivity growth and food production? Would water availability be a binding constraint in the future? What pace of introduction of sustainable intensification of agricultural production is required to avoid natural resource limits become binding constraints to global food security?
3. **Income generation and distribution**. How to consider inequalities within and across countries? Is a cross-country convergence in the long run a necessary consequence of the evolution of economic systems or has it to be imposed as an exogenous assumption? What is the extent of changes in dietary patterns in response to income changes? How different paths of assets accumulation across different households, due to, for instance, different propensities to save and different preferences for investment will influence future income distribution? Is the impact on global food security the same whether a same amount of income distribution is achieved through smallholder agricultural productivity growth or through redistributive policies, such as social protection programs?
4. **Investment for development and domestic asset generation**. How to quantify investment needs in rural areas? To what extent needed investment has to be public vs private? To what extent it has to be foreign vs domestic? How to assess investment needs for the achievement of specific development targets? How to assess investment needs for Climate-Smart Agriculture (CSA) or any better form of mitigation agriculture? What investment is required to increase smallholders' productivity? To what extent would such (mostly public) investment "crowd in" private investments in farming and should one assume a different degree of responsiveness to private investments between smallholders and larger commercial farmers?
5. **Structural change**. To what extent will people, who leave the agricultural sector in response to e.g. increased mechanization or decreasing land availability**,** find a job in other sectors? What are the output and employment growth requirements of non-agricultural sectors across countries and regions

to absorb excess agricultural labor under transformative processes of agriculture? Is job absorption by the manufacturing and service sector a necessary consequence of increased productivity in agriculture? Is a jobless structural change plausible? Can strong international migration result as a consequence of a jobless structural change in some countries? Can the adoption of CSA practices contribute to job creation in agriculture?

6. **Emerging global food value chains (GVCs)**. Is the organization of food production through GVCs an efficient mechanism towards food and nutrition security? What would further expansion of GVCs mean for price setting, intra and cross country value added distribution and stability? What consequences would further expansion of GVCs – under existing patterns – have on market competition, income distribution, natural resource use and degradation?
7. **Climate change and development perspectives**. What is the impact on land productivity and total factor productivity in agriculture of unabated climate change (no substantial changes in greenhouse gas (GHG) emission reductions) by 2030-50-80? What would be the implications for food security and incomes and employment in the agricultural sector? To what extent mitigation and adaptation costs differ across countries and regions, given differences in mitigation potential and vulnerability to climate change? To what extent can payments for environmental services related to GHG absorption influence income generation in the agricultural sector and/or in rural areas? What are impacts on prices of agricultural commodities?
8. **The Energy-Agriculture-Climate Change nexus**. What would be the food security consequences of major expansions of biofuel production, which could be for example due to efforts to reduce GHG emissions? To what extent will the adoption of CSA techniques change energy needs of the agricultural sector? How would a global carbon tax (on energy alone or on all emission sources) affect food security and food prices?

Mr Bellù highlighted that the GPS team values very much cross-institutional partnerships and cited as examples the participation of GPS in the activities of the global economics team of the Agricultural Model Intercomparison and Improvement Project (AgMIP), and the contribution the ESA director to the Steering Council of AgMIP.

Mr Martin Pineiro, advisor to the FAO Director-General, stressed that the economy evolves with considerable fluctuations, implying that the modelling efforts of the GPS team should not concentrate on a linear extrapolation of trends but instead support the analysis of alternative future scenarios in a consistent framework.

4 Session 2: Desired modelling framework properties

Session 2 was structured as a sequence of five sub-sessions addressing the key questions which need to be accounted for in FAO's long-term projections as outlined in Section 1 above. For the purpose of the workshop the key questions were clustered in the following five domains:

1. Population growth, migration, and limits to natural resources,
2. Income distribution,
3. Investment and finance,

4. Structural change and global food value chains,
5. Climate change and the Energy-Agriculture-Climate Change nexus.

For each sub-session, a main speaker provided an opening contribution focusing on the following aspects:

- **Existing modeling frameworks**. Which existing models you are familiar with would be best suited to capture the key questions raised for the long-term scenario analysis?
- **Additional features required**. What features of those models would need to be added or fundamentally changed in order to become a meaningful fit?
- **Capturing climate change in models**. How are climate change and its impacts captured? If not, how could those be incorporated?
- **What to model and what not.** What questions and/or variables could be equally well (or perhaps better) dealt with outside the modelling framework?
- **Endogenous vs exogenous variables**. Which aspects should best be handled endogenously in a general equilibrium setting and which may be handled through partial equilibrium approaches or kept exogenous?
- **Endogenous vs post-solve calculations**. To what extent "post-solve" calculations, i.e. further calculations based on models' solutions, of selected variables provide additional info on the questions at stake?
- **Recursive-dynamic vs other models.** Is a recursive-dynamic model a good starting point for addressing the questions? If not, what would be the alternative?

Each presentation was followed by a discussion. All participants were also asked to send to the GPS team written comments on the specific topic.

4.1 Session 2A: Population growth, migration and limits to natural resources

In the opening presentation, Mr Sherman Robinson underlined the strong link among population growth, migration and limits to natural resources. Given that FAO, as an organization dealing with food and agriculture issues, has a comparative advantage on agricultural markets and structural transformation in agriculture rather than projecting demographic changes, he suggested to keep population growth as an exogenous variable and to study scenarios with different population growth specifications. He complemented that migration across countries is difficult to represent endogenously, mainly because of lack of data and methodological challenges.[2]

Discussion

The participants suggested that FAO should indeed borrow population projections from the UN population division and/or the literature. It is however important to understand how these projections have been derived and what the underlying assumptions are, to ensure that projected scenarios are internally consistent.

[2] See van der Mensbrugghe and Roland-Holst (2009) for an approach to treat migration between countries endogenously based on LINKAGE.

Mr Rob Dellink stressed the role of education in determining population projections (family size is for example linked to the education level of the mother), as well as in determining economic outcome (human capital) and suggested that education has been taken into account in the quantification of the population projections for the so-called Shared Socioeconomic Pathways (SSPs). Mr Peter Wobst explained that education determines the skills of labor force and hence labor productivity, whereas there is a link between investment, education and human capital. Investment for example in CSA is meant to generate sustainable employment in rural areas enhancing livelihoods and reducing population movements both within the country (e.g. urbanization) and between countries (i.e. external migration). Mr Alex Izurieta added that the long-term migration in particular depends both on employment and on education policies.

The link between migration and income differentials was highlighted by Mr Wobst. Remittances should be considered to properly account for the income levels, as Mr Rui Manuel Dos Santos Benfica pointed out.

A further aspect to disentangle is the link between migrations and the environmental conditions, as Mr Wobst suggested. Environmental distress (for example lack of fresh water) may well cause migrations and can have implications for food and nutrition security in specific regions.

Different types of migration may well cause different effects on dietary patterns (for example urbanization, international migrations from rural or from urban areas). Mr James Thurlow commented that it is relevant to look at the implications for import demand and structural changes in agriculture and in the entire economy due to the different types of migration.

Mr Hans Lofgren summarized that in the FAO global economy model population could be exogenous by age cohort, including exogenous migration and labor force participation by age and gender; it would be possible to define parameters that reflect alternative scenarios for fertility, mortality, and migration, all of which would have implications for labor markets. The UN population projections could be used to populate these scenarios. Internal migration, however, (i.e. urbanization) is far from complete in several less industrialized countries and may need to be modeled endogenously and be linked to structural transformation and income evolution as Mr Dominique van der Mensbrugghe suggested. Regarding limits to natural resources, land and water future availability needs to be accounted for when projecting food and agriculture on the long-term. There was, however, no unanimous conclusion on whether land and water markets should be dealt with in a global economy model, and hence have the GAPS-PE model allocating them the specific agricultural activities, or the GAPS-PE model should be expanded to account for these specific factor markets.

Mr Thurlow suggested that land use dynamics should be considered separately for smallholders and large scale farmers so as to account for structural transformation in agriculture. He explained that in Africa whereas the average farm size is dropping, large farms seem to become larger, to expand the land they own and to hire more skilled labor.

4.2 Session 2B: Income distribution

Mr Thurlow gave a thorough presentation on how to account for inequality between and within countries and what the strengths and weaknesses are of literature to account for a representative household (Type 1, typical for standard Computable General Equilibrium (CGE) models), disaggregate the single household into subnational groups (Type 2, for example followed by MIRAGE-HH and MyGTAP), use household surveys to inform microsimulations, which are in turn linked to a global economy model via changes in factor incomes and prices (Type 3, for example GIDDS) and follow a fitted income distribution to consider several representative households (Type 4, for example MAMS). He proposed that FAO consider a hybrid approach having namely a global CGE model that allows for country specific income typologies linked to fitted income distributions.

Discussion

The participants commented that household surveys do not cover long time series, hence it is challenging not only to identify income distributions specific to countries but to age them so as to depict long-term effects. Furthermore, as Mr van der Mensbrugghe added, it is important to be clear if the income distribution refers to before or after tax income and what the institutional framework within each country is that arranges the distribution of before and after tax income.

Mr Vos commented that the distribution of income is closely linked with the distribution of assets, hence the dynamics of asset accumulation should be taken into account as well, even though this will be challenging to do for assets related to the agricultural sector as (a) appropriate distinctions between types of assets (land, livestock, trees and plants, etc.) would have to be made; and (b) since changes in asset holdings may be as much influenced by risk-coping behavior, absolute constraints to asset availability (e.g. land), incomplete markets for such assets, and/or production related investment behavior. The participants stressed the importance of modelling factor markets and of tracking the sources of income and recommended to study the MAMS model for a built-in mechanism to account for changes in factor ownership and the R123 model for remittance flows. Mr Wobst stressed that models with differentiated households should ideally track consistently, for each household, the sources of primary income (i.e. skilled, urban worker, etc.), and that behavior for maximizing income should refer to the household, rather than to the individual. Disaggregating, however, factor markets is not trivial and as Mr Robinson commented, the more factor markets are disaggregated, the more one needs to worry about mobility of factors across sectors. Furthermore, the definition of the disaggregated factors may be different across countries, making any modelling approach more complicated. Given that income distribution and generation is particularly relevant to poverty and undernourishment (in turn related to Sustainability Development Goals 1 and 2), the participants suggested to attempt to consider rural and urban households disaggregated by income quintiles.

Data availability regarding factor markets and income distribution is the main constrain for any modelling exercise. Mr Piero Conforti highlighted that, while African countries are somehow covered in household surveys, countries with large populations such as China, India and Southeast Asian countries are rather poorly covered. To overcome data problems, the participants proposed to devote time to develop scenario so as to assume a distribution that accommodates best a specific scenario narrative, for

example log-normal or to draw a synthetic sample from log-normal distributions, as Mr Robinson proposed. Mr Dellink suggested to refer to the analysis of income distribution in the SSPs (see for example van Ruijven *et al*., 2015). To note, the design of scenarios should take into account policy questions that are relevant to the FAO analysis. The analysis may become more complicated if policies involve changes in relative prices (such as green growth policies) and hence in expenditure, for which hardly any data exist.

On the modelling approach, the participants agreed that the tool should be flexible enough to accommodate country specific information and income distributional forms, and should enable to track down structural change in countries currently characterized by low levels of industrialization and modern service activity. Mr van der Mensbrugghe expressed skepticism about addressing within-country income distribution in a global model other than linking it to micro-based models. Mr Lofgren stressed the limited ability of any model to generate reliable results of within-country changes in poverty and income distribution over the long run (say, projecting to 2050 or 2080). He stressed, however, that because between-country income distribution may explain roughly 80 percent of global inequality a simple treatment of within country inequality may serve the purposes of FAO long-term projections. This obviously depends on the policy scenarios that need to be analyzed. The model could be coded in a modular fashion enabling to have a single representative household for countries with very low extreme poverty rates (and where extreme poverty is irrelevant), but with multiple representative households groups in countries where extreme poverty is substantial. Doing so it would allow to use readily available data without precluding the possibility to carry out post-simulation microsimulation analysis.

4.3 Session 2C: Investment and finance

Mr Izurieta presented how investment and financial markets are depicted in the United Nations Global Policy Model (GPM). Particular features of this model is that domestic consumption is affected by changes in financial markets and investment is determined by consumption (rather than savings) and is modelled as an adjustment process towards a stable capital-output ratio, with short term effects from financial variables (interest rate, foreign and domestic lending) and an accelerator term. Investment in turn stimulates productivity growth.

Discussion

Part of the discussion was about the GPM model and in particular if the model could be adjusted to accommodate the analytical needs of FAO long-term projections. Given that the GPM model represents financial institutions in detail, the participants acknowledged that investment and finance are indeed weak points in CGE models. Given, however, the scope of FAO long term projections, they did not recommend the GPS team to model explicitly financial markets but rather to focus on those investment related issues that are relevant to small scale farmers. Mr van der Mensbrugghe commented that is it not clear to what extent the modelling paradigm of GPM focuses on near- and -medium term disequilibria versus a long-term equilibrium and how this approach can address the needs of the GPS team. Mr Robinson explained that models have a domain of applicably and he feels that representing financial markets falls outside the domain of which a FAO global economy model should be applied to. He added

that agriculture investments (public and private) are rather addressing resource constrains than being driven by financial markets.

The participants agreed that the global economy model of FAO should explicitly model production and the supply side of economic systems and recommended not to try to apply the GPM model beyond its domain of applicability. Mr van der Mensbrugghe added that results on macroeconomic variables from GPM could be used to inform scenarios which call for a more detailed analysis at FAO.

Mr Vos explained that for the purposes of the GPS team an aggregate investment function is not helpful as often as FAO needs to deal with sector-specific investment and, in particular, with investment in agriculture. He asked to what extent short-term behavior is the main driver of agricultural investments, locking in technologies and infrastructure with long-term consequences. High-risk (e.g. weather variability) and high-uncertainty (e.g. climate change impacts) sector typically lead to underinvestment in agriculture, even though model-based estimates of relative profitability would predict capital flowing into the sector. The question is how best to build in the related risk and uncertainty factors in a CGE structure. Likewise the availability and quality of infrastructure will be critical determinants to be considered. Finally, the imperative of making agriculture sustainable would require specification of investment (and input-use) functions that would allow for simulations to related technology shifts, while accounting for adjustment costs.

Along these lines, Mr Wobst commented that both public and private investment are relevant to the agricultural sector. There are small scale investments in agriculture linked to private savings and consumption – in particular the capacity to generate own savings and self-consumption. It is however challenging to represent these in any modelling exercise and hence scenario analysis can help to link the modelling work with findings from case studies and examine the effects of alternative mechanisms to save and to invest.

Modelling public investment is not trivial, as the participants commented. Mr Thurlow suggested that government investments in agriculture and the general economy could be represented exogenously and hence explore their effects on the agricultural sector through scenario analysis. Depending on the scenario analyzed, public agricultural investment could be considered through a total factor productivity elasticity (see for example Diao *et al*., 2012), be split into types of investment (improved variable inputs like seeds and fertilizer, irrigation, rural roads, etc.) and hence be considered through unique elasticities for each type (based on empirical literature). In a next step the different public expenditure patterns could be simulated to in order to measure benefits and trade-offs, albeit for the latter an external public agricultural investment model may be needed.

Mr Lofgren suggested the GPS team to include data on public investment and public capital in the database and to represent public investment separately in the global economy model the GPS team will develop/adopt but, to formulate the code and the model in such a way to use this variable, will be optional and country specific and, if included in any given country, could refer to one or multiple investment and capital types. Examples of possible categories are aggregate agriculture, crop production, livestock production, and forestry. The efficiency terms in the value-added functions of the sectors which are positively affected by one or more types of public capital stocks would need to include an endogenous

component that depends on the product of ratios between current and base-year capital stocks for each relevant type of public capital, with each ratio raised to an elasticity term that is scaled to make sure the public investment type mimics an exogenous internal rate of return. Such a formulation would permit public investment to influence the allocation of private investment across sectors but not its total volume (unless private savings or FDI respond to profitability). Whenever public investment exceeds (falls short of) public savings, the value of national savings available for private investment falls short of (exceeds) private national savings. Some mechanism should be added to ensure that this adds to (deducts from) the claims of households on government revenues, perhaps by paying households the rent on private savings absorbed by the public sector. This would be a simple way of mimicking government borrowing at an interest rate that typically is lower than rates of return on private capital by a wide margin.

Private investment in agriculture is often linked to particular policies (for example credit facilitation) but may also be crowded out by other policies, whereas the type of investment is very much dependent by the availability of natural resources (e.g. land and water). The investment function for agriculture should be hence expanded and be linked to constraints on land and water supply.

Endogenously representing the link between investment and technological change is crucial in any modelling exercise. CGE models are deeply structural models, specifying explicitly factor and sectoral productivity growth, whereas some models represent separately the growth of vintage capital, as Mr van der Mensbrugghe commented. Experience from the Phase 1 of AgMIP suggested that there is not much of empirical evidence on how to introduce technological change other than to calibrate the model to a given GDP path and derive assumptions on the factor and sectoral productivity growth. Sensitivity analysis showed that the assumptions on the most productive sectors on the long-term can affect more price changes than the macroeconomic assumptions per se (see for example Robinson *et al*., 2014). Back-casting was suggested as an exercise to give guidance on validating the derived assumptions on the derived productivity growth due to technological change.

Mr Thurlow commented that it is easier to tie savings and finance to investment and rates of capital accumulation, rather than endogenising the choice of productivity enhancing technologies. To model, for example, energy investments, the GPS team may make use of an energy investment model which selects optimal investments in the long-run (e.g. TIMES or MARKAL). An analogous optimization routine could be set to determine which investments increase the most agricultural productivity.

Mr Lofgren suggested that installed capital should not be perfectly mobile. To impose this, the capital employment by sector could be for instance constrained not to decline from one year to next by beyond the depreciation rate. In case this limit is binding (which should rarely be the case), a sector-specific endogenous capital scarcity rent adjustment factor would need to be activated so as to bring the sector-specific rent below the economy-wide level. New capital (acquired due to investment) should be allocated to sectors depending on relative profitability of each sector.

4.4 Session 2D: Structural change and global food value chains

Mr Dellink presented how the modelling tools used in the OECD Environment Directory are used and linked for baseline creation and scenario analysis. The ENV-GROWTH model (a macro model) is used

to quantify long run macroeconomic scenarios, assuming gradual convergence of developing countries towards OECD ones. ENV-LINKAGES is calibrated to replicate the macro baseline, the projected trends on food consumption, livestock feeds, land supply and land efficiency obtained by running the partial equilibrium model IMPACT using the same macro baseline. Trade patterns are not harmonized with IMPACT due to differences in the two models. Parameters and projected trends on energy markets are taken over from the World Energy Model and elasticities on land supply from the IMPACT model. Mr Vos recommended that FAO start first by defining the exact policy questions and then define what is relevant to include in the model, considering the expertise in FAO. The identification of elements to be modelled has to be complemented by the identification of elements to be assumed as exogenous and elements to be handled qualitatively, which can be provided by third sources. He urged the GPS team to start from existing scenarios but not to take them at face value for issues directly related to the policy questions which need to be addressed.

Discussion

Mr van der Mensbrugghe commented that it is not straightforward to calibrate the food demand of a global economy model such as ENV-LINKAGES to the results of a partial equilibrium model of agricultural markets such as IMPACT with only a partial representation of food value chains. Processed food and food demand embodied in services is depicted implicitly in the partial equilibrium model, as its data describe the primary equivalent of food consumption, whereas it is depicted explicitly in a global economy model. Furthermore, a consistent full consumer utility function is absent in the PE model due to its partial nature, while it should be a desirable feature of a global economy model. He proposed to use model "inversion" as dialogue between the GAPS-PE and the global economy model rather than to impose the result of the one model as "strait jacket" to the other.

Regarding modelling structural change in agriculture and allowing shifts from small holders to commercial farmers (and vice versa), Messrs Dellink and van der Mensbrugghe suggested to consider the different farming practices (e.g. small scale and commercial farming) as discrete technologies and aggregate their output. The latter could be perfectly substitutable or not. Mr Conforti, however, commented that it is not trivial to represent in a global model small scale farming because it is not clear what criteria and thresholds to use worldwide in order to identify smallholders. It might be more pragmatic to first have several case studies and then try to incorporate them in a global model.

Structural change patterns observed in the last ten years in low-income countries, particularly in Africa, refer to exit from agriculture and engagement to non-farming activities in rural areas. Mr Thurlow explained that these patterns may well continue in the next two or three decades because of the expected increase of the rural population. This, in turn, implies that it is relevant to the GPS team to represent explicitly rural households and depict such structural changes from farm to non-farm sectors.

The question whether net trade positions should be aligned between a CGE and a partial equilibrium model, stimulated thoughts on whether bilateral trade needs to be represented in FAO's general economy model and how to be able to project trade creation and not only net trade diversion. Representing bilateral trade vs. net trade gives the flexibility to simulate cases that assume regional fragmentation of markets. An Armington specification of imports, however, is haunted by the problem that small initial bilateral

trade shares stay small in simulations, no matter how big shocks are in bilateral trade policies. This problem is not visible in a net trade specification because the initiation of imports is not at bilateral level. Mr van der Mensbrugghe mentioned that there is some ongoing work at the GTAP center on modelling firm heterogeneity which could potentially be of interest to the GPS team once finalized.

On representing global food value chains, Mr Robinson commented that the IMPACT model is set to represent explicitly food processing activities covered in FAOSTAT. Mr Marco Sanchez-Cantillo suggested that a detailed representation of demand for agricultural commodities and a good activity-commodity mapping would be sufficient. Mr van der Mensbrugghe stressed the importance of a plausible relationship in prices and that this cannot be depicted in a partial equilibrium framework as long as farm gate prices are transmitted entirely to consumer prices.

4.5 Session 2E: Climate change and the Energy-Agriculture-Climate Change nexus

Mr van der Mensbrugghe summarised key issues that would need to be looked at when modelling the economic and food security implications of climate change as well as challenges for the agricultural sector arising from changes in energy and climate. He commented that the variance might be more critical than changes in the mean temperature and precipitation, albeit different climate change models do not agree on either. Climate change should affect not only the availability of natural resources but also the availability and the productivity of capital and labour and have visible implications on non-agricultural sectors (e.g. health, energy demand and tourism). Adaptation to climate change is up to a certain degree autonomous in an economic system but can be also exogenous, depending on the type of investments to specific adaptation actions/technologies. Modelling options involve integrated assessment exercises or scenario analysis using the results of General Circulation Models (GCMs) and crop models. The role of bioenergy and especially of biofuels is crucial in determining the energy-agriculture nexus although it is not clear to what extend bioenergy is emissions reducing. Given the uncertainty on bioenergy related technologies as well as on the substitutability of bioenergy with conventional technologies, it is important to represent bioenergy cost curves for various technologies. Mr van der Mensbrugghe stressed the fact that doing it involves a several persons and years research agenda and suggested to the GPS team to look at the GCAM model.

Discussion

Mr Vos opened the discussion by stressing that climate change mitigation and adaptation reactions are linked to future investment towards specific actions/measures and hence should be determined by the projected sectoral investments. He wondered to what extent ongoing modelling exercises capture this link endogenously or are based on exogenous assumptions and what sources informed the latter. He added that policy questions expand also to the supply side of carbon emissions whereas addressing them requires tracing the carbon footprint throughout the economy (e.g. if a carbon tax were to be applied, which sector should be taxed, and which part of the value chain?).

The participants confirmed that climate change needs to be addressed by the modelling efforts of the GPS team but it is a complex issue which will inevitably require an interdisciplinary approach. Mr Robinson commented that such an approach should consider: impacts of climate change on temperature

and precipitation (GCMs), infrastructure needs, water availability and water management, impacts on crop and livestock yields and finally the economic implications which can be addressed both by partial and general equilibrium models. Mr Dellink explained that at the OECD, the effects of climate change are depicted within the "Cost of Inaction and Resource Scarcity; Consequences for Long-term Economic Growth" (CIRCLE) project, in which ENV-LINKAGES is coupled with findings from biophysical models regarding changes of crop yields and of fish supply, capital and land losses in coastal zones due to rise of sea level, diseases and labour productivity losses because of increased temperature, changes in energy demand and in tourism and capital damages from hurricanes.[3] Work on quantifying the effects of adaptation options has been carried out partially with IMPACT and partially with ENV-LINKAGES.[4] He recommended that the GPS team approach climate change through scenario analysis and uses the SSPs as starting point, since the storylines entail challenges to mitigation and adaptation. Specific aspects of climate change could be informed exogenously from biophysical modelling, others (e.g. investment needs) should be modelled endogenously, whereas some further aspects would need to be handled only qualitatively in the beginning. Mr Sanchez-Cantillo recommended that the GPS team look at the model CLEWS, used in UN-DESA, which is a framework set up for integrated assessments and captures the life cycle of key materials.[5]

Scenario analysis should look at the implications of the way climate change is paved in. Mr Sanchez-Cantillo explained that a moderate change of climate may well lead to easier and less costly adaptation, whereas a repetition of extreme events may increase the costs for mitigation and adaptation. Mr Dellink warned that it may be quite difficult to model extreme weather events since they can be quite uncertain, whereas attention should be given to the specific assumptions underlying all exogenous variables so that there is no overlap: for example yield shocks derived from crop models may indirectly be affected by assumptions on droughts.

Some participants pointed out that there is little consensus on the direction of the climate change impacts on crop yields due to different ways of dealing with carbon fertilization. Detailed analysis through sharp crop models could contribute to fill this knowledge gap, but the GPS team does not have any comparative advantage in getting involved in such detailed investigations.

The participants confirmed that analysis should look into both mitigation and adaptation options. Scenarios that target different global temperature increases, including the ones that target less than 2°C after 2030, are of interest. Climate Smart Agriculture practises and perhaps further specific mitigating/adapting practises versus non-mitigating/adapting ones (e.g. crop rotation, irrigation) could be represented as discrete technologies whose selection could be autonomous and preferred for example by imposing a tax to the non-mitigating/adapting technology. It would be easier to model discrete technologies in a global economy model because cost curves are explicitly represented (compared to a

[3] The latest report of OECD within the CIRCLE project can be retrieved under: http://www.oecd.org/env/cc/the-economic-consequences-of-climate-change-9789264235410-en.htm

[4] A contact person to give more information on modelling the economic effects of adaptation options at OECD is ada.ignaciuk@oecd.org

[5] Modelling tools used at UN-DESA are presented under: https://unite.un.org/analytics/desa/modellingtools
More on how CLEWS is used in combination with the other modelling tools is given in:
https://github.com/UN-DESA-Modelling/CLEWS_Global

partial equilibrium model such as GAPS-PE). It should be kept in mind, however, that mitigation and adaptation technologies are interdependent as for example mitigation may make adaptation less necessary in the future.

Finally, to the question if biofuel use should be represented in the GAPS-PE model or depicted in the global economy model, the participants recommended the GPS team to handle biofuel use rather exogenous and assume that biofuel supply will be as high as to fulfil mandates and blending targets.

5 Session 3: Implementation of a suitable modelling framework for FAO's GPS team

In the third and final session, some tentative conclusions were presented by Messrs Lofgren and Sanchez-Cantillo. They summarized the workshop findings by browsing the various contributions in the preceding sessions, focusing on key elements that are of interest to the GPS team and the way to operationalize a suitable modelling framework at FAO.

5.1 Main features of a suitable modelling framework

Both speakers agreed that FAO would indeed need a global economy model because such a model offers a consistent framework for representing the linkages between trade in goods and in services, labor and population migration, foreign aid and capital. Moreover, it is necessary to address analytically issues that cannot be answered by a partial equilibrium model such as: a) competition between factors of production and common resources, b) welfare, poverty and inequality – especially when changes in non-agricultural income are involved and c) structural transformation and the overall role of food and agriculture in the broader economy.

Mr Lofgren stressed the fact that the FAO team should have a thorough knowledge of the model and should be able to operate, adjust and update both the model and its database independently. The model should incorporate standard features of the models in the literature but should also include those specific features to address the needs that are particular to FAO's long term projections. Given the limited time to have an operational model for the next forward looking exercise of FAO it will be important to set strict priorities on the desirable features needed to be added to a core model for the near term. The team should decide whether to use an existing model and adapt it or develop a mode from scratch or something between these two extremes, depending on the own work program and deadlines to meet.

Mr Lofgren pointed out several practical pitfalls that may require a work plan so as to avoid and overcome them:

- The GPS team is a small team and so the modelling endeavors are vulnerable to any mobility of the staff.
- Often models become unnecessarily complex and hard to understand because of features not well documented and/or no longer needed, which often require data not readily available. Time should be planned to consolidate the work annually, to remove and to add parts to the core version of the model and to update the documentation.

- Often modelling work is arranged in a way that it requires an unnecessarily large scale of specific operational skills; for example when several types of specific software is used for the basic operation of the model. Discipline would be needed to adhere to the software selected for the core model and expand only when needed for optional modules.
- Model and database management is often not handled efficiently, increasing substantially the time needed to adjust the model and the data to a new application. There should be a distinction between the core version of the model (fully documented) and special application extensions (where documentation might be less crucial), whereas all changes and extensions should be introduced in a modular fashion.
- Often models are developed in a direction that do not address the analytical needs of their clients. The model itself but also the work program of the GPS team should meet and nurture the demand for analysis at FAO and should demonstrate its usefulness.

The model should draw on data from available global datasets as much as possible. The GTAP database but also UN sources, FAOSTAT for agriculture, the World Bank, the IMF and the R23 model database for official and/or private transfers between regions should be among the main datasets to look at. The modelling framework should be flexible enough to accommodate adjustments in country-specific data if deemed necessary and to aggregate or disaggregate regions depending on their relevance for international trade. It should also allow for a different aggregation of households, public investment and production factors per country depending on the relevance of each for a country's agricultural sector. Part of the review process should aim to validate the results not only at global level but also at country level.

The speakers stressed that each model has a different domain of applicability. Mr Lofgren explained that there are areas better addressed by a partial equilibrium model or a national general equilibrium economy model. These are for example regional issues, dietary change, nutrition, intensification vs. extensification of agricultural production per agro-ecological zone as well as rural and urban migration. The latter could be better depicted by a single country analysis because it is not easy to define whether a locale is urban or rural given that population density differs per country and so the cutoff point is not the same across countries. The linkages between urban and rural are also complex, especially in case households live in rural areas but work in urban centers, whereas they are haunted by lack of data. There is hardly any sectoral data on value added and production disaggregated into rural and urban and the disaggregation cannot be based on any simple assumption of sectoral patterns given that part of agricultural production can be urban and part of industrial and services production can be rural.

The GAPS-PE should be linked to the global economy model so as to avoid inconsistencies between the results of the two models. Mr Lofgren advised to keep the links simple and strictly prioritized, while being able to run each model independently. The exact approach on how to link the two models should depend on their role in the model based analysis and the outcomes each model will need to highlight. Mr Lofgren explained that if both models will have a central role in the analysis, then the disaggregated results from the GAPS-PE should be reasonably close to the aggregated ones from the global economy model. The key variables to harmonize should be agricultural GDP, gross output, income and prices. When price signals are on areas where non – agricultural demand/supply matters, the GAPS-PE model should use prices (or rents) from the global economy model. In an analogous way and whenever the price

signals are on areas where agricultural demand/supply matters, then the aggregate quantities supplied or demanded by agriculture in the global economy model should follow the price projections of the GAPS-PE model. Such adjustments may be related to productivity and intermediate input coefficients in the global economy model and the parameters of output demand functions in the GAPS-PE. Mr Lofgren explained that a global SAM, which is an input to the global economy model and can be generated for every solution, has a large number of cells that are aggregates of payments in the GAPS-PE. If the base year is the same for both models, it should be feasible to strive for a high degree of or even full initial consistency. In principle, over time the two models could be made to generate identical results via an iterative procedure in a between-year modules that communicates results between the two models. In practice, this would be prohibitively costly computationally. But when needed, selected parameters for a full scenario in each of the two models may be adjusted on the basis of a comparison of results from a preceding run.

Mr Sanchez-Cantillo added that in a parallel path the GPS team should work on improving the partial equilibrium model it has developed (GAPS-PE) and in particular add some nuance on biophysical dimensions by linking it to appropriate integrated frameworks such as the CLEWS model. He stressed the fact that such a framework can enable to represent the link between land and water use with energy demand, issues that are particularly critical to any further climate change analysis. He suggested that representing biophysical boundaries properly should be in fact the first priority of the team.

5.2 Specific features of a suitable modelling framework

Population

Mr Lofgren repeated that whereas population by age cohort should be considered exogenously, readily available projections from UN's World Population Outlook could be used to reflect the impact of alternative scenarios on fertility, mortality and migration on labor supply by age and gender.

Income distribution and poverty

Mr Lofgren reiterated that any model has limited ability to generate reliable projections for within country income inequality and poverty in the long-term given the scarce empirical evidence describing past and current income distribution. Since between countries income distribution may explain some 80% of the global inequality, a simple representation of within country inequality may be adequate to assess overall inequality. The easiest option would be to assume a log-normal distribution of income for each representative household per country and to post-calculate the associated poverty and inequality per scenario analyzed. The model itself should be flexible to accommodate a different number of households per country/region, for example varying from a single household for countries with very low extreme poverty rates to multiple representative households for countries with substantial extreme poverty. Existing poverty rates and Gini coefficients could be used to inform the post-calculations. Post-microsimulation analysis should not be excluded a priori although it is a resource intensive exercise. Mr Sanchez-Cantillo added that depicting non-factor income (e.g. remittances) and the way it is distributed is very important as remittances account for some 20% of the global GDP. Representing

remittances may implicitly address migration and population changes. Mr Dellink suggested to refer to the analysis of income distribution in the SSPs (see for example van Ruijven *et al*., 2015).

Investment and capital mobility

Mr Lofgren summarized that private and public investment should be represented separately in the database of the global economy model given the importance of the latter for agricultural and rural policies and development but the model should be formulated in such a way that the separation is optional. For private investment and capital, on the one hand, it may be easiest to have only one type of investment and to code the model so that the allocation of new investment be fully efficient as determined by relative profitability. To possibly reflect some rigidities in allocation, one additional parameter for each country could be added. On the other hand, installed private capital should not be mobile (see Section 4.3). For public investment and capital, the model should be flexible to accommodate one or multiple investments in the various countries, depending on data availability. Detailed recommendations on how to represent endogenously public investment allocation and capital accumulation preceded in Section 4.3.

Climate Change

As the focus should be on agriculture, a simple treatment of the links between greenhouse gas emissions and non-agricultural activities may be sufficient.

5.3 Final Discussion

Mr Vos opened the discussion by explaining that FAO has initiated work for a new forward-looking long-term scenario analysis on the future food security and nutrition. The new report World Food and Agriculture Towards 2080 should be ready by early 2017. The modelling work should help create a coherent and credible baseline up to 2080. The baseline would then serve as reference for future updates and analysis of alternative long-term scenarios, to provide quantitative underpinnings for the overall analysis of the new report. Take away message from the workshop was that FAO would be well advised to develop its own global computable general equilibrium model by adapting an existing framework which comes closest to its needs and link this to the GAPS-PE and, in the future, other modules (e.g. models on physical aspects of the water, land and energy nexus). A key capacity of the global CGE would be to capture interlinkages of investment allocations and asset distribution (especially those relevant to the determination of agricultural productivity and food supply), income distribution shifts, natural resource constraints, and economy-wide impacts on trade and prices. The first step would be to use existing model frameworks (GAPS-PE and one of the existing global frameworks out there, ENVISAGE or GLOBE, for instance) and prioritize one or two key improvements to meet the needs of the global projections work and then to find a practical link between the two frameworks. FAO will need to help of partners around the table to get this done.

Mr Dellink pointed up that it requires quite some effort and resources to develop a model; the time needed to calibrate an existing CGE model is already substantial. Given the small size of the GPS team and the tight deadline for FAO next forward-looking exercise, he advised the GPS team not to be overambitious,

especially during the first year, and to set up a simple core model in a way that modules can be added easily in the future.[6]

Mr van der Mensbrugghe suggested to arrange the work in two parallel tracks: the first one should be on improving further the GAPS-PE model and the second on the global CGE model. He recommended to focus in the beginning only at the development of agricultural income over time and look at income distribution in a later stage.

Regarding which global CGE model to use, the participants recommended to base the selection on models that are open source and that would require the lowest possible costs for the GPS team to operate it, to introduce necessary adjustments and to use it in a consistent way with the GAPS-PE model. Messrs van der Mensbrugghe and Robinson recommended to avoid using forward looking dynamic models, as the complications to set them and inform its parameters are very high compared to the insights such models could provide. Some participants recommended to consider as a starting (core) global CGE model either the model ENVISAGE, because of its quite thorough treatment of capital allocation, the explicit treatment of the capital-energy nexus, the environmental module addressing carbon emissions and the inclusion of environmental change damage functions, or the GLOBE model, for its simpler structure and because a version of it is already used by IFPRI together with the partial equilibrium model IMPACT (hence linking GLOBE to GAPS-PE could benefit from the IFPRI experience). Mr Dellink commented that the MAGNET model could also be reviewed as well because it is agriculture oriented (e.g. land supply representation and inclusion of bioenergy sectors).

Last but not least, the participants stressed the need to develop a storyline for the baseline upon which to identify the specific features of the modelling exercise. The modelling tools should be designed in a way to allow to quantify in a consistent way the storyline. Megatrends to consider should be for example biofuel penetration, urbanization, climate change but also how quickly biophysical boundaries can be reached. The policy questions, however, would need to be narrowed down taking into account the small size of the GPS team and the deadlines.

6 Conclusions of the Global Perspectives Studies team for immediate follow up

Through the workshop the GPS team aimed at achieving three objectives:

1. To identify the key features of a model for long-term scenario analysis suitable to address the key development questions of FAO's global perspectives work.
2. To identify approaches to implement such model features and to determine the extent to which they are already embedded in existing models.
3. To trace a step-wise pathway to endow the FAO GPS team with a suitable and operational GEM-SAF with desirable features.

Thanks to the contributions of the participants all the objectives set for the workshop were achieved. The findings of the workshop clearly indicated that the use of a suite of models is the most advisable strategy

[6] The OECD team at the Environment and Economy Integration Division has four modelers that can handle ENV-LINKAGES and ENV-GROWTH.

for GPS. This comprises (at least) of a recursive-dynamic global CGE model and the existing global partial equilibrium model of FAO, GAPS-PE. The two models need to be consistently employed, focusing on specific results and depending on the needs of each modelling exercise. The CGE model should provide boundaries to the GAPS-PE model in terms of sectoral output and food expenditure, which in turn should lead to a broadly consistent net trade position of each country and consistent productivity shifters.

Regarding the global CGE to adopt as a basis, two candidates emerged as most suitable: ENVISAGE, for its thorough treatment of capital formation and use and for the treatment of climate change, and GLOBE, for its simpler structure, which is easier to adapt. The GPS team will proceed on the two parallel tracks of choosing the most suitable CGE model and adapt it to the maximum extent possible, given the available time, while further refining the GAPS-PE model.

Regarding the identification of the key features of the CGE model for long term scenario analysis and the approaches to implement such features, the debate was articulated around the eight sets of questions clustered in five working sessions, presented in the introduction of the workshop.

The summary findings retained by the GPS team as guiding principles to adopt and adapt a CGE model are reported here below.

1. **Population growth and migration**. A suitable model for GPS does not need to include a fully-fledged demographic model, despite the fact that, as highlighted during the workshop, many demographic developments, including migrations, depend on variables of interest to GPS (income opportunities, availability of natural resources, investment in education and in human capital etc.). As population is the basis to determine labor supply and final demand, it is important considering age cohorts, exogenous migration, labor force participation by age and gender, fertility, mortality, and migration, all of which would have implications for labor markets. The impacts of these population dynamics could be captured through alternative scenarios, based on exogenous information. However, efforts could be made to model internal migrations (urbanization), particularly important to depict structural changes of economic systems, or, at least, to model separate representative households according to their location (urban vs rural) and impose on them exogenous trends depending on alternative scenarios.
2. **Limits to natural resource uses.** While detailed land and water requirements will be analyzed through the GAPS-PE model, the CGE model should provide feedbacks of limits to natural resources on income generation, notably on value added by sector, land (and water) remuneration and price levels. Land use dynamics should be considered separately for smallholders and large scale farmers so as to account for structural transformation in agriculture. Limits to natural resources in the CGE model, should be consistent, to the maximum extent possible with the ones used in the GAPS-PE model. Should those limits in the baseline or under alternative scenarios become binding, they will also contribute to determine price levels and shape international trade flows. For the abovementioned reasons, the adoption of a CGE model that satisfactorily deals with limits to natural resources is recommended.
3. **Investment for development and domestic asset generation**. Both public and private investment have to be dealt with. As in many instances (in reality and in forward-looking

scenarios) public investment is deemed to influence productivity, the adoption of a model already dealing with the link between public investment and productivity is recommended. In any case, pragmatic ways of linking total factor productivity or factor-specific productivity to public investment need to be explored. Public investment could influence the allocation of private investment through factor/sector specific productivity shifts, but may compete with private investment for available domestic savings. New capital (due to investment) should be allocated to sectors on the basis of the relative profitability of each sector. Existing capital could be sector-specific, particularly in agriculture. However, the issue of excess installed capital in a sector whose relative importance progressively decreases, needs to be addressed. The adoption of a model properly dealing with dynamic sector-specific capital adjustments is sought. The issue of asset ownership and related implications for income distribution across households is important because asset ownership can be a determinant of food security, particularly for poor/food insecure households in the base year. Modeling asset generation and related distribution is key for exploring food security issues. The CGE model for GPS has to address this issue.

4. **Income generation and distribution**. Modeling income distribution is required to investigate, among other things, consumption and saving potential of households. Consumption potential relates to food access, while savings ensure stability across periods, through asset ownership and related remuneration. Capturing inequalities in a CGE model may be challenging. However, introducing multiple representative households in the CGE allows capturing the income differences between groups of the population, although not within these groups. Calibration of the model in the base year should rely to the maximum extent possible on existing information. GPS will attempt the distinction between rural and urban representative households, in turn split on a simple representation of asset/income level. The different fiscal treatment of households will be considered, to capture the after-tax (disposable) income distribution, as well as the different propensities to save and invest of the different households.
5. **Structural change**. In many instances, modeling structural change requires assumptions regarding relative shifts of productivity across different sectors, which can occur through exogenous technological and/or institutional factors or through investment. To model structural change, the GPS needs a clear definition of what type of "structural change" to model. If structural change is merely intended as a shift from smallholding subsistence agriculture to commercial farming, both sectors have to be present as "*discrete technologies*" in the CGE model. The relative importance of the different sectors will be determined, in the baseline and in alternative scenarios, by relative shifts of productivity. The implications for factors' use, and specifically for labor allocation and/or unemployment, will depend on the way factors and factor markets are modeled. The exit of labor from (small scale) agriculture and the entry in non-farm/non-agriculture sectors does not necessarily imply the existence of migration/urbanization processes, as long as off-farm activities develop in rural areas. The CGE model for GPS has to take into consideration these structural changes. The extent to which the issues of localization of emerging activities and population will be addressed in the CGE model, and more specifically, the extent to which the rural-urban shifts of people match the agricultural-non-agricultural shifts of labor force deserves

further investigation. The exploration of selected multi-sector dynamic country-level models dealing with multiple (rural and urban) households may be a source of inspiration.

6. **Emerging global food value chains and international trade**. In many instances, CGE models allow modelling imports and exports of primary agricultural commodities, domestic processing of food using both domestically produced and imported commodities, exports and domestic consumption domestically processed food as well as imports of processed food. However, global food value chains are not modeled as such, i.e. as supranational agents acting on the global arena with their own behavioral supply demand and investment relationships. While GPS will consider to the maximum extent possible sector-specific foreign investment and related expatriated profits in the CGE model, global value chains, at least in the immediate, will not be modeled as such. However, the CGE model has to address bilateral trade issues as some scenarios will refer to fragmentation of, inter alia, trade relationships, carbon emissions related to trade and impacts on trade of technological developments. Broad consistency between net trade flows from the CGE model and the GAPS-PE models will be sought, keeping into consideration that in the GAPS-PE model for many products consumers' demand is expressed in primary commodity equivalent, while in the CGE model it is expressed in terms of processed goods.
7. **Climate change and development perspectives**. Climate change is at the core of the forward looking exercises that GPS has to run. As climate change will affect land productivity and the productivity of other factors as well as availability of natural resources, the GPS team will inform its work on the basis of existing bio physical models and related findings on the named variables, which are already fed into the GAPS-PE model. The CGE model will host key parameters to allow accommodating shifts of land productivity, productivity of other factors and resource availability under different climate change scenarios. As assumptions on different exogenous GDP levels that inform the calibration process of the CGE model have to be consistent with climate change scenarios, attention will be given to parametrize the CGE model in such a way that this consistency is achieved. Moreover, because it is of interest to understand the extent to which the adoption of selected agricultural practices would reduce carbon emissions, a CGE model with an environmental module that measures carbon emissions under different scenarios would be suitable. Coexisting "discrete technologies", whose adoption will be triggered by incentives or disincentives, such as public investment or taxation, will be modeled. In addition, the CGE model to be adopted by the GPS would preferably provide the possibility to explore in an integrated way the mutual relationships between carbon emissions and economic activities, i.e. how carbon emissions damage economic activities and, in turn, how economic activities produce carbon emissions. This allows exploring the feedback effects of adopting mitigation technologies within and outside agriculture.
8. **The Energy-Agriculture-Climate Change nexus**. As energy, together with transport and agriculture is one of the mayor sources of carbon emissions and strong nexuses exist among energy, agriculture and climate change, the CGE model for GPS has to allow considering: a) the extent to which the agricultural sector could meaningfully reduce the consumption of energy through technological changes; b) how the agricultural sector could become a sink of carbon and to what extent agricultural revenue could be generated through carbon absorption; c) what are the

effects of different climate change scenarios on land productivity and land use; d) the extent to which bio-energy demand would compete with other agricultural activities and e) how all these factors would affect in the long-run net carbon emissions of agriculture.

On the basis of the findings of the workshop, the GPS team will take immediate steps forward, such as:

1. Refinements of the GAPS-PE model in areas already object of updating and improvement (rebasing with most updated FAOSTAT data, improving demand systems, specification of bio-physical boundaries, improvements in the livestock module etc.);
2. Adoption of an open-source well documented global CGE model with most of the features highlighted above;
3. Design of storylines reflecting baseline and alternative forward looking scenarios, to be associated with assumptions related to key quantitative variables, as a basis for modeling exercises;
4. Installation, exploration and calibration of the existing version of the suitable CGE model;
5. Adaptation, to the extent possible, to the GPS team's needs of the existing CGE model;
6. Establishment of partnerships in key areas of work such as: adaptation of the CGE model and related database to host different representative households and related investment and asset accumulation processes; modeling concurring "discrete technologies" regarding e.g. structural change and/or mitigation and triggering changes in their relative weight; advice on integrating the GAPS-PE and the CGE model findings; maintain consistency between assumptions regarding exogenous drivers of the CGE model and different climate change scenarios; other areas, to be determined, if needed.

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Annexes

Annex 1. Agenda

08.30-09.30	Welcome, round of the table and opening remarks Session 1: *Looking into the future: key questions for the next FAO forward-looking exercise* (10 min per presenter followed by 25 min discussion)	Speakers: Kostas Stamoulis (FAO) Rob Vos (FAO) Lorenzo Giovanni Bellù (FAO)
09.30-10.30	Session 2: *From questions to models: desired modeling framework properties.* Sub-session A: Population growth, migration, and limits to natural resources Chair: Aikaterini Kavallari (FAO) (for each sub-session: 5 min introduction, 20 min presentation, 10 min individual drafting, 25 min discussion)	Opening presentation by: Sherman Robinson (IFPRI)
10.30-11.00	Coffee break	
11.00-12.00	Session 2: sub-session B: Income distribution Chair: Rui Manuel Dos Santos Benfica (IFAD)	Opening presentation by: James Thurlow (IFPRI)
12.00-13.00	Session 2: sub-session C: Investment and finance Chair: Gennaro Zezza (UNICAS)	Opening presentation by: Alex Izurieta (UNCTAD)
13.00-14.00	Lunch Break	
14.00-15.00	Session 2: sub-session D: Structural change and global food value chains Chair: Marc Müller (FAO)	Opening presentation by: Rob Dellink (OECD)
15.00-16.00	Session 2: sub-session E: Climate change and the Energy-Agriculture-Climate Change nexus Chair: Hideki Kanamaru (FAO)	Opening presentation by: Dominique van der Mensbrugghe (Purdue University)
16.00-16.30	Coffee break	
16.30.17.30	Session 3: *Implementing a suitable model framework: Elements for design and operationalization* Chair: Piero Conforti (FAO)	Summary presentations by: Hans Lofgren (World Bank) Marco Sanchez-Cantillo (UN-DESA)
17.30-18	Wrap-up and conclusions	
19.00-21-00	Buffet dinner at: FAO, Aventino Room 8th floor	

Annex 2. List of participants

Name	Affiliation	Contact
Lorenzo Giovanni Bellù	FAO – Global Perspectives Studies Team	LorenzoGiovanni.Bellu@fao.org
Rui Manuel Dos Santos Benfica	IFAD	r.benfica@ifad.org
Piero Conforti	FAO – ESS	Piero.Conforti@fao.org
Rob Dellink	OECD	rob.dellink@oecd.org
Jippe Hoogeveen	FAO – NRL	Jippe.Hoogeveen@fao.org
Alex Izurieta	UNCTAD	alex.izurieta@unctad.org
Hideki Kanamaru	FAO – NRC	Hideki.Kanamaru@fao.org
Aikaterini Kavallari	FAO – Global Perspectives Studies Team	Aikaterini.Kavallari@fao.org
Hans Lofgren	World Bank	hlofgren@worldbank.org
Dominique van der Mensbrugghe	Purdue University	vandermd@purdue.edu
Marc Müller	FAO – Global Perspectives Studies Team	Marc.Mueller@fao.org
Steven Were Omamo	IFAD	sw.omamo@ifad.org
Martin Pineiro	FAO – OSP	Martin.Pineiro@fao.org
Sherman Robinson	IFPRI	s.robinson@cgiar.org
Marco Sanchez-Cantillo	UN-DESA	sanchez-cantillo@un.org
Kostas Stamoulis	FAO – ESD	Kostas.Stamoulis@fao.org
James Thurlow	IFPRI	j.thurlow@cgiar.org
Rob Vos	FAO – ESA	Rob.Vos@fao.org
Peter Wobst	FAO – SP3	Peter.Wobst@fao.org
Gennaro Zezza	Universita' di Cassino e del Lazio Meridionale and Levy Economics Institute (Bard College)	zezza@unicas.it