Journal of Global Economic Analysis, Volume 5 (2020), No. 1, pp. 1-27.

Shaping Baseline Scenarios of Economic Activity with CGE Models: Introduction to the Special Issue

By ROB DELLINK[a], DOMINIQUE VAN DER MENSBRUGGHE[b] AND BERT SAVEYN[c]

This introductory paper to the special issue on shaping long-term baselines with Computable General Equilibrium (CGE) models presents the main challenges and opportunities in constructing numerical scenarios of future economic activity using CGE models. Better understanding the role of socioeconomic drivers in baseline scenarios allows for better understanding of policy scenarios. The combined set of papers in this special issue provides three key contributions to the literature. First, it highlights the need and room for improved transparency and possibly harmonisation of baseline assumptions, while avoiding herding behaviour where all models make identical assumptions. Secondly, it raises awareness of the crucial role of the baseline in quantitative dynamic CGE analysis. Thirdly, it provides the means and incentives to modelling teams to construct more sophisticated baselines by showing practices used in advanced large-scale models and highlighting the role of different drivers. It is the objective of this special issue to set a research agenda, encouraging greater attention to baseline scenarios in the research literature.

JEL codes: C68, D5, O11, O40.

Keywords: Baseline scenarios; Computable general equilibrium models; Dynamic analysis; Long-term economic projections.

---

[a] Organisation for Economic Co-operation and Development Environment Directorate, 2 Rue Andre Pascal, 75116 Paris, France ((e-mail: r.dellink@gmail.com).
[b] Center For Global Trade Analysis, Purdue University 403 West State Street, West Lafayette, IN 47907 ((e-mail: vandermd@purdue.edu).
[c] European Commission, Joint Research Center, Calle Inca Garcilaso 3, Sevilla, 41092 ((e-mail: Bert.SAVEYN@ec.europa.eu).

1. Introduction

In the early 1990s, the first global economic trade models were being developed to assess the economic consequences of a potential conclusion to the Uruguay Round. Each modelling team spent many person-years developing a unique global database using different data, base year, sector and regional configuration and methodology. One consequence of this was that a significant portion of any comparison exercise was devoted to understanding the differences in the databases. Even a simple change in base year could change the numeric results by a two-digit percentage amount simply due to dollar inflation. This situation inspired the development of the GTAP database (Aguiar et al., 2016; Aguiar et al., 2019) that largely resolved the issue of data harmonization, as well as providing a global public good that saved resources and man-power.

Since the early 1990s, dynamic Computable General Equilibrium (CGE) models have increasingly been used to analyse impacts of shocks to the system to economic activity in the medium- and long-term future. This has led to a situation somewhat similar to the state of static global CGE modelling in the 1990s. Comparative assessment of results from dynamic CGE models is difficult without understanding the underlying drivers of their projections, even if some are harmonized to a limited set of exogenous drivers – such as Gross Domestic Product (GDP) and demographic developments. For example, the cost of climate mitigation policies depends strongly on assumptions regarding the future availability and cost of fossil fuel resources, the cost and market share of alternative technologies, changes in energy efficiency and producer and consumer preferences.

Quantitative policy analysis is typically presented in relation to a scenario – i.e. a numerical projection – that assumes the economy will change under the influence of future changes in the socioeconomic drivers (and policy assumptions that are beyond the domain of interest of the policy analysis). These so-called baseline scenarios provide a reference point for evaluating the impact of policy changes or other events. Constructing better baselines serves two purposes. First, it can improve the insights into plausible and internally consistent projections for future economic activity in absence of policy changes or other shocks. Such projections can be extended to related indicators that are connected to economic activity, such as energy security, poverty, nutrition and climate change damages. Secondly, it can help explain the differences between insights obtained by global dynamic CGE models insofar these are grounded in the underlying baseline characteristics.

This special issue has the objective to draw more attention to the development of baseline scenarios in the CGE-related literature. It provides a first step towards better understanding of the role of economic baseline projections. This issue makes three key contributions to the literature. First, it highlights the need and room for harmonisation of baseline assumptions where possible, while avoiding herding behaviour where all models make identical assumptions. Secondly, it raises awareness of the role of the drivers of baseline projections in quantitative dynamic analysis that in turn influence the quantitative assessment of policy shocks. Thirdly, and not least, it provides the means and incentives to modelling teams to construct more sophisticated baselines by showing practices used in advanced large-scale models and highlighting the role of different drivers.

The papers in this special issue have benefited from the exchange of detailed information amongst more than 25 modelling teams. This comparison exercise started with a workshop organised by Organisation for Economic Co-operation and Development (OECD) and the Center for Global Trade Analysis (GTAP) in January 2018, as documented in Appendix A. Since then, different author teams have carried out in-depth analysis of the baseline assumptions in the various models, the results of which are presented in the papers in this special issue.

This overview is set up as follows. Section 2 provides a brief description of how CGE baseline projections are typically dealt with in the existing literature, without trying to be exhaustive. Section 3 goes a step deeper by looking at typical modelling approaches used in the large-scale global models that feature in the papers in this special issue. Section 4 describes the key contributions of the papers in this special issue, while Section 5 presents an overview of all the models and modelling teams that have participated in the project that has led to this special issue. Finally, Section 7 identifies some cross-cutting areas for further development.

2. CGE-based baselines in the literature

Simulated policy results depend on a plethora of assumptions, regarding the policy shock, the parameters that govern the reactions of households and firms to these shocks. However, the underlying baseline may be arguably the most important factor that drives the comparative results. The role of the baseline has until now received too little attention and is rarely subjected to thorough investigation. The reasons for this are plentiful: creating a baseline is very costly but necessary; creating multiple baselines is often prohibitively costly and can be hard to communicate – although sensitivity analysis with respect to specific baseline parameter assumptions is more common; the CGE modelling community has no tradition of baseline comparison exercises (unlike the sectoral modelling communities). An additional problem is the lack of transparency of baselines. Typically the baselines are never reported in detail, moreover they can be significantly influenced by aggregation and parameter formulation, and there is a reproducibility problem by other teams or even model versions within the same team.

Few modelling teams present their baselines in detail and even fewer are published after a peer review process. Published baseline papers include Dixon and Rimmer (2005), Sokolov et al. (2005), Chappui and Walmsley (2011), Chateau et al. (2011), Britz and Roson (2019) and Rey et al. (2018, 2019). None of these go into much detail on how the assumptions about the main drivers affect the key economic projections, and these individual baselines are very hard to compare as they differ in sociodemographic assumptions, calibration procedure and parameter assumptions on key drivers. Box 1 presents different approaches to dealing with interactions between current behaviour and future states of the world.

Box 1. Dynamic projections with CGE models

CGE models have different approaches to the future (Ginsburgh and Keyzer, 1997). Many models assume that agents (households and firms) base their behaviour solely on past information, and are agnostic about the future; these models are called recursive-dynamic. Other models assume that agents have information about the future; one common assumption is perfect foresight (Chaudhuri, 1989; Barro and Sala-i-Martin, 1995). Still other models have more complex assumptions, such as adaptive expectations (where some naïve expectations about the future inform current behaviour) or overlapping generations. The key advantage of a recursive-dynamic model is that it relies solely on data and model parameters and can be solved iteratively for one period at a time, where the periods are linked by updating the endowments of production factors and assumptions on dynamic changes to production technology and preferences. Effectively, in each period current utility is maximised, ignoring the effects on the future. The perfect foresight models are instead solved over the entire time horizon by maximising the present value of current and future utility. Dellink (2005) compares these assumptions for a national CGE model and finds that, at least for baseline construction, the choice about forward-looking behaviour is less important than the assumptions on exogenous trends that are fed into the model. Empirical estimates suggest that, in reality, consumers look ahead to some extent, but do not maximise their utility until infinity (see Srinivasan, 1982; and Ballard and Goulder, 1985). McKibbin and Wilcoxen formalize this in the G-Cubed model that assumes only a portion of agents have fully consistent expectations (see McKibbin and Wilcoxen, 1998).

The simplest dynamic models rely on the assumption of a steady-state, or a balanced growth path. By assuming that the economy is on a balanced growth path, all key variables (consumption, GDP, supply of production factors) grow at the same speed (Barro and Sala-i-Martin, 1995) and the only data requirements are the savings rates, depreciation rate and the rate of technological progress. This simple approach is at odds with using SAMs to describe the base year, as economies are generally not on a balanced growth path in the base year.

Large-scale CGE models – whether they are recursive-dynamic or forward-looking – therefore reject the balanced growth assumption and focus on the adjustments of the economy over time using a more detailed set of exogenous trends. This requires more detailed calibration of specific drivers, not only macroeconomic, but also sectoral.

Efforts to harmonise the drivers of economic activity across models is largely lacking, and model comparison exercises that include CGE models are relatively scarce. The Energy Modelling Forum (https://emf.stanford.edu/) sometimes includes CGE models (e.g. Weyant et al., 2014), but is focused on energy policy scenarios, with little room to investigate the consequence of modelling assumptions regarding baseline trends on international trade, capital accumulation, etc.

Long-term baseline projections are especially important for long-term economic issues, such as climate change. The Intergovernmental Panel on Climate Change (IPCC) has recognised this and has asked the modelling community to create standard scenarios for future greenhouse gas (GHG) emissions and their economic drivers. These so-called Shared Socioeconomic Pathways (SSPs; Riahi et al., 2017) are widely used in the climate modelling community, but also in the broader global modeling community, as the five SSP scenarios form a consistent set of socioeconomic drivers that can be used for various types of models. The economic projections in the main emission scenarios are provided by Dellink et al. (2017), while Leimbach et al. (2017) and Crespo Cuaresma (2017) provide alternative projections, using the same qualitative assumptions and the same demographic drivers. Fully disaggregated sectoral SSP projections for direct calibration of dynamic CGE models have not yet been developed.

The experiences of the SSP scenario construction exercise lead to three main conclusions for CGE baseline construction. First, it can be helpful to create a structured mapping of the main dimensions of baselines (such as "fast convergence, low population growth" etc.). Researchers can use such a "binning matrix" for labelling their own baseline and thus succinctly summarise the main features and assumptions by placing it in a specific bin. Secondly, more transparency and consistency between the different model assumptions can be obtained by using structured and consistent narratives (e.g. "a world with strong global cooperation and fast technological growth") and harmonised megatrends (concerning e.g. globalization and servitization); these narratives and harmonised megatrends then form the backbone for all specific numerical assumptions (e.g. productivity improvement in specific sectors). Thirdly, harmonising on a limited set of key drivers (such as demographic developments) allows for more structured investigation of the influence of other model assumptions and eases comparison across models by limiting the variation across models on the key drivers (see e.g. Nelson et al., 2014).

3. What shapes large-scale CGE-based baselines?

The key objective of a baseline projection using CGE modelling is to create an internally consistent set of future trends for key economic variables, ensuring that demand equals supply at all times. Based on a set of exogenous trends that drive the model -- for instance population growth and technological progress -- projections of economic activity at the regional and sectoral level can be made.

The core of the models is the description of linkages between sectors, commodities and regions in Social Accounting Matrices (SAMs) that underlie the specification of economic behaviour in CGE models (for example the GTAP database). These SAMS typically consist of input-output tables or make and use tables to reflect how different economic agents are linked to each other through market transactions: it specifies which sectors use which inputs and the disposition of output. SAMs represent the economic situation for a specific (base) year. By combining the exogenous trends that govern how drivers of economic activity change over time with the base year SAMs, a full set of SAMs is constructed for future periods – that reflect projections of both quantities and prices while maintaining overall accounting consistency.

In general, there are two ways to describe the exogenous trends: econometric estimation and calibration (Harrison et al., 2000). Estimated models derive econometric information from historical data within the model and use those to populate the parameter values of the model (for instance, savings rates and labour-capital substitution elasticities). Calibrated models rely instead on existing information about parameter values, for instance published estimates of substitution elasticities, coupled with expert judgement for those parameter values where insufficient data are available. Alternatively, estimation-based models use historical data on the relationship between a dependent variable and drivers to establish parameter values, while calibration-based models rather observe (or assume for future periods) a dependent variable value and deduce the parameter value of a driver based on a pre-set qualitative relationship between the two. Due to the more tractable data requirements, the calibration approach is used by virtually all models, although many try to include publicly available estimated parameters as much as possible. The econometric approach can be useful for aggregate macro-economic variables and parameters, however, it becomes much more problematic when looking at specific sectors or issues (like climate), as the future is likely to witness structural changes that were never observed in the past (e.g. electric vehicles may be part of the baseline).

Parameters (such as cost shares and preference parameters) in a CGE model are calibrated to a set of assumptions on key elasticities (e.g. income and price elasticities) and the reference database. Most comparative static exercises take this as their starting point and assess the impacts of policy (or other shocks) relative to this calibrated reference year. If the models are all using the same SAM (e.g., GTAP data), then model comparison largely involves evaluating assumptions on the key elasticities, model closure (e.g. fiscal and balance of payment closure) and market behaviour (perfect vs. imperfect competition, fixed or flexible wages, etc.).

A dynamic baseline is composed of a number of key elements:

- A set of exogenous drivers that are outside the scope of the model, for example population, but can also include a number of other elements such as crop yield growth, energy efficiency improvements, or potential targets for harmonization, such as GDP. In the case of the latter, modelling teams may take different approaches to achieve the baseline GDP target: labour embodied technological change (potentially differentiated across economic activities), total factor productivity growth, etc. (see Fouré et al. in this issue). The approach taken will have different implications for structural change and relative factor returns and will also be conditional on other choices such as the growth of employment, national savings, land and natural resource supply, etc.

- Assumptions on changes in technology and cost structures in production (see Chateau et al., this issue), and changes in consumer preferences (see Ho et al, this issue), and possibly other demand shifts, including preferences for imports (see Bekkers et al., this issue). Changing cost structures can be derived from external sector-specific expertise—for example in agriculture and energy. There has been less emphasis on the evolution of consumer preferences, albeit all models—particularly focused on agriculture and food, attempt to line-up with stylized facts such as declining budgetary expenditures on agriculture and food (Engel's Law) and increasing consumption of proteins such as meats (Bennett's Law). Whether in the context of energy and emissions or trade, one additional dynamic lever is how to introduce new activities, commodities and economic relations (such as a new bilateral trade node). One stylized fact of development economics is the 'densification' of input-output and trade relations as economies graduate from low- to high-incomes. In the context of energy-based analysis—the future availability and cost of new energy carriers and technologies plays a significant role in assessing future emission profiles and the impact of carbon pricing regimes on these profiles (see Faehn et al., this issue).
- Key assumptions on how future economic outcomes influence current decisions (see above), i.e. expectations – this is most notably the case for savings and investment decisions and thus indirectly current production capacity and consumption decisions. Most large-scale dynamic models of the CGE variety are recursive dynamic and thus savings and investment choices rely solely on past or current economic indicators. Eventually, even in recursive dynamic models, savings and investment decisions are likely to be influenced by steady-state assumptions, for example stabilization of rates of return.
- Assumptions on which policies affect baseline trends. Mostly, baselines are calibrated such that current policies are included in the baseline. Anticipated future policies within the domain of the study are excluded from the baseline, but assessed as a policy scenario. Ideally, anticipated policies outside the domain of the study should be included in the baseline; this is typically done through assumptions on changes in the exogenous drivers over time rather than through the explicit modelling of these policies. For example, an agricultural study would include (the

effects of) the current EU's Common Agricultural Policy, as well as the effects of macroeconomic and climate change policies, but not any change in tariffs on agricultural and food commodities.

How much of these elements matter will depend to some extent on the time horizon of the study in question. One anticipates much less structural change in a time horizon of 5-15 years than beyond. Trade analysis relies very much on detailed trade statistics and in general focuses less on (long-term) baselines. Agricultural analysis tends to be more forward looking with baselines up to 10-15 years, which is aligned with the time horizon of the design of agriculture support schemes. In the context of climate change studies, 2050 is often the minimal horizon – albeit there is ongoing work with a 2030 horizon given the framework of the Paris Agreement – with many studies pushing out to 2100 and beyond, in part driven by the inherent lags in the carbon cycle and climate models.

The focus of a baseline depends on the area and context of the analysis. Outcomes of specific studies may be much more dependent on sector-specific assumptions, rather than the broad set of assumptions. For example, trade analysis has a detailed calibration of the trade statistics, while climate change analysis has more focus on energy sectors. Nonetheless, all major models have significant sectoral detail and international trade flows as competitiveness issues are at the centre of any CGE analysis.

4. Overview of the papers in this special issue

A typical dynamic baseline projection from a large-scale CGE model involves several steps. Although different modelling teams follow different procedures, and not all steps are compulsory, a generic flowchart may look as in Figure 1. It should be emphasised that these steps are not necessarily sequential, apart from step 1. CGE models are large simultaneous systems of equations, implying that the calibration procedures affect each other and must be balanced iteratively.

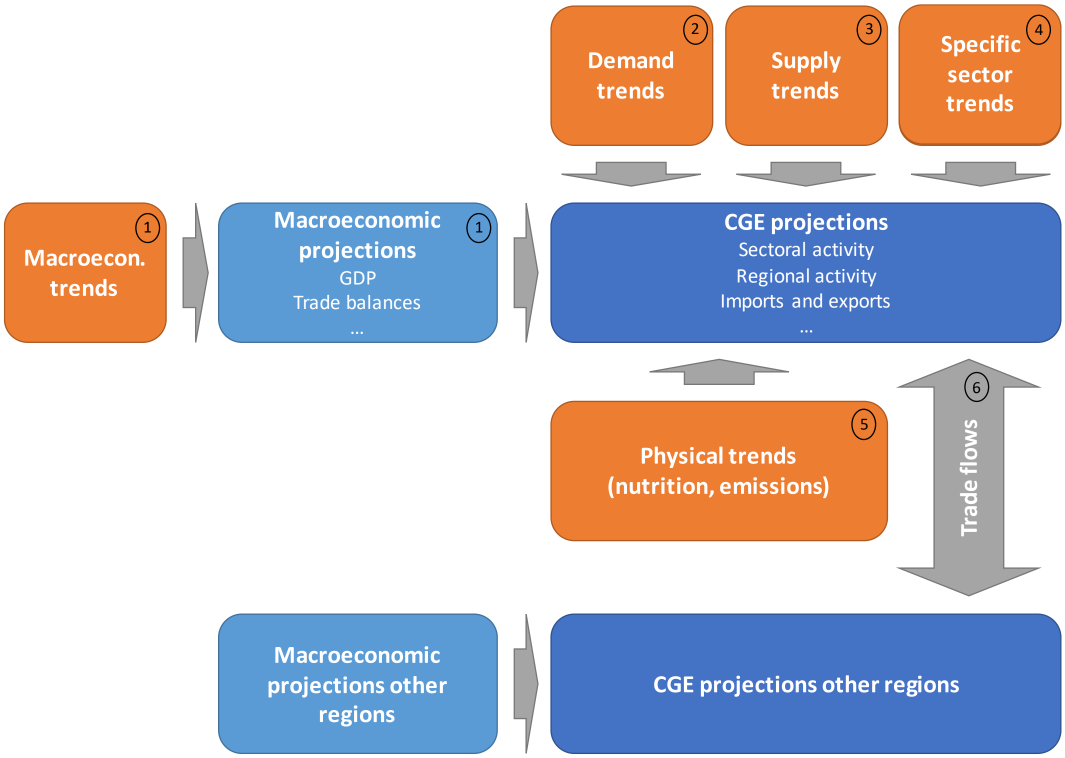

Figure 1. Generic flowchart of a dynamic CGE model baseline projection

Source: Author construction`s.

First, macroeconomic trends are either produced with a dedicated macroeconomic model, or taken from exogenous sources (*step 1*). These macroeconomic trends summarise how the economy in the future is projected to be affected by demographic trends such as population (and workforce) growth, aging of the population, etc. Other macroeconomic trends may include drivers of capital accumulation and drivers of the productivity of the economy, e.g. assumptions on the evolution of total factor productivity (TFP). This first step is discussed in detail in the paper by Fouré et al. (this issue). They find that the total factor productivity calibration using an external source of GDP projections is in general well documented and based on sound and standardized projections. But large discrepancies remain when it comes to projections of primary factors. The paper highlights the importance of maintaining consistency between the different external sources for projections; for instance, the population assumptions behind the GDP projections used should be identical to the population projections in the CGE baseline; furthermore, the energy price projections used to calibrate natural resources should come from a source with – at least broadly – comparable GDP growth assumptions. It also proposes some factor-specific recommendations. Regarding the labour force, the authors recommend incorporating the difference between working-age population and active population in long-run baselines, and dedicating more research effort on the projection of skills to build better data and projections. Regarding capital accumulation, the paper identifies simplistic assumptions on savings (for instance, a constant savings rate) or current account (constant current account or convergence to zero) that should be avoided and replaced by theoretically and empirically sound alternatives, as discussed in more depth in Bekkers et al., 2020. Finally, the paper identifies simple assumptions on fossil natural resources or land availability that can be taken on board easily, even in models not specialized in energy- or agriculture-related issues, to provide a general framing for the (long-term) revenues generated by these factors.

In the CGE model, these macroeconomic trends are combined with the base year accounts that disaggregate the economic sectors and commodities. Further assumptions are then needed to project into the future. *Step 2* involves the addition of specific assumptions on the evolution of the composition of final demand. This involves elements such as assumptions on the evolution of preferences and savings. Assumptions on the evolution of investment demand and government expenditures are also included in this step. The paper by Ho et al. (this issue) discusses this topic. They summarize the advantages and disadvantages of different functional forms commonly used for specifying consumption demand for commodities and describe the methods used to adjust these consumption functions over time to incorporate expected changes. Income elasticities differing from one are well established, as discussed in Ho et al. (this issue), and one expects the share of income-inelastic goods to fall over time. The paper discusses how this is especially problematic for food demand in fast growing economies with rapidly changing consumption patterns. Many common functional forms used do not capture these expected changes and the parameters need to be adjusted over time. The paper also discusses modelling energy demand where there is the challenging task of incorporating items such as electric vehicles that are not yet observed in the base period in many countries. The paper also notes that trends in the composition of investment should ideally be incorporated into the baseline.

The natural complement to assumptions on demand are the assumptions on the evolution of the supply side of the economy (*step 3*). This step tends to concentrate on assumptions for supply-side drivers of structural change, specifically primary factor efficiencies and changes in intermediate demand over time (Chateau et al., this issue). A typical trend here is the increasing share of services in total intermediate demand in all production sectors. On the basis of illustrative simulations, the paper illustrates some good practices in mimicking supply-side features such as structural change in the baseline calibration process of CGE models. An important step that should not be avoided is to make assumptions on the different rates of change of productivity across sectors. The paper also discusses good modelling practices on how to change labour productivity across sectors to achieve specific targets for changes in sectoral total factor productivity or changes in labour efficiency. Good modelling practice also includes dynamically adjusting the demand structure of some production sectors to drive a projected shift in the sectoral composition of the economy towards some desired external trends, such as the increase in the demand for services in production or changes in energy demand. Finally, the paper discusses some non-economic sources of structural changes including the projected rise of environmental damages and how these can affect production functions.

The next two papers in this issue use more detailed sector information to dig deeper into on the evolution of key sectors (*step 4*) and link the baseline trends to physical indicators (*step 5*). The developments of technologies and resource use in agriculture and the main energy producing and consuming sectors have been most popular sector-specific explorations in CGE baselines. Where technology detail is available through stand-alone sectoral models, linking the CGE models with specific sectoral models has become a common way of exploiting available sectoral expertise. Such linking is discussed in Delzeit et al. (this issue). The paper systematically compares and discusses approaches of linking CGE models to external sectoral models to inform the CGE baseline calibration procedure and discuss challenges and best practices. The paper divides approaches into one-way linkages, where outputs from one model serve as exogenous inputs in another model, and two-way linkages, where the feedback between both models is taken into account in order to iteratively reach better convergence of overlapping variables between both models.

Given the frequent use of model linkages in CGE modelling, modellers expect to enrich and strengthen their analyses but often encounter inconsistencies between CGE and more sector-specific models that challenge robust linkages. Modelling consortia such as GTAP (Van Tongeren et al., 2017) and AgMIP (Nelson et al., 2014) provide a means for collaboration and advancement on the modelling frontier with a focus on greater consistency in the data being used within linked models and on procedures for implementing relatively advanced two-way linkages. Best practices include transparent decisions to apply one-way or two-way linkages, harmonisation of input data, and the use of response functions instead of calibration to a single point. For future research, Delzeit et al. (this issue) suggest testing different linking approaches within and across modelling efforts where differences between stand-alone and combined solutions should be reported and the choices in model linking are transparently motivated.

Faehn et al. (this issue) also address the agriculture and energy relevant production processes, but with a particular focus on links with physical indicators such as greenhouse gas emissions (*step 5*). Specifically, it examines how the development of production modes and technologies impact – and are impacted by – (mitigation of) emissions. The paper thus highlights how steps 4 and 5 can be exploited simultaneously to provide a detailed representation of how the energy system, as well as agriculture and land use, is linked to emissions of both CO_2 and non-CO_2 greenhouse gases and to climate change. Faehn et al. (this issue) present how CGE models can build novel and upcoming technological and behavioural detail into baseline projections. This includes linking procedures as described in Delzeit et al. (this issue), but also the integration of technological detail in the CGE models and the dynamic adjustment of productivity, substitution and other parameters to represent the relevant technological and sectoral trends. Specific attention is paid to modelling and projection procedures relevant for particular sectors, including fossil fuel extraction, power generation, transportation, manufacturing industries, buildings, agriculture and forestry. The paper also discusses knowledge gaps requiring for further analysis of emissions and abatement options, including data challenges and the understanding of the interdependency between climate change and other societal, economic, technological and environmental trends and challenges.

Finally, economies do not operate in autarky, but are linked through bilateral trade flows and international capital flows (*step 6*). Bekkers et al. (this issue) look at different methods to represent the evolution of trade flows in CGE models. They compare different approaches chosen by CGE modellers on the most important trade features of their models: the way trade flows are modelled and the size of trade elasticities, the behaviour of the trade balance, the growth of trade, the role of energy prices, the modelling of zero trade flows, phasing in future trade policies, and capital income and remittances. Where possible, these discussions are supported by model simulations. The authors conclude that there is consensus about the use of nested Armington preferences, whereas modellers differ significantly on the way the trade balance is modelled (fixed trade balance, capital flows responding to rates of return, converging trade balances, or an empirical approach based on estimated Feldstein-Horioka equations). Most CGE models do not address the discrepancies between baseline and historical trade growth. The paper emphasises that more research is needed on the following topics: a better coverage of other components of the current account (capital income and remittances) and the inclusion of net foreign debt and asset positions, projecting trade growth based on historical patterns, and better tools to model the rapidly growing digital economy.

Each of these steps is explored in detail in the papers in this special issue. The papers have been written by authors from different modelling teams, using detailed information provided by all modelling teams that participated in this study. Building on the information available from the different models, the various chapters aim to identify commonalities, good practices and areas for further development of the methodology (as well as major data gaps).

5. Modelling groups contributing to the study

Twenty-six models participated in this effort, mostly from teams that are directly or indirectly involved in the GTAP consortium. Invitations were also circulated to known CGE modelling groups outside the GTAP community; a few of them are also involved. Nonetheless, the group of models has a strong bias towards models that are operated by teams from OECD countries. Developing country participation in the study was unfortunately limited. The author teams of the papers in this special issue have therefore aimed to integrate examples of published modelling results from other teams where possible. Table 1 presents the participating models and institutions, and provides information on where the main model descriptions are available (key reference and website, when available); Appendix B presents full model and institution names.

Table 1. Participating institutions and models

Model	Institution	Key reference	Website
ADAGE	US EPA	Ross (2009)	
AIM	NIES	Fujimori et al.(2017a,b)	
DART	Kiel Uni.	Klepper et al. (2003), Calzadilla et al. (2012)	www.ifw-kiel.de/institute/research-consulting-units/the-environment-and-natural-resources/articles/dynamic-applied-regional-trade-model-dart/
EC-MSMR	ECC Canada		gc.academia.edu/Departments/Economic_Analysis_and_Modeling_Division/Documents
ENGAGE	UCL	Winning et al. (2017)	www.ucl.ac.uk/energy-models/models
Envisage	GTAP		mygeohub.org/groups/gtap/envisage-docs
Env-Linkages	OECD	Chateau et al. (2014)	oe.cd/env-linkages; www.oecd.org/environment/modelling
EPPA	MIT	Chen et al. (2017)	globalchange.mit.edu/research/research-tools/eppa
EU-EMS	PBL	Ivanova et al. (2019)	
Exiomod	TNO	Bulavskaya et al. (2016)	www.tno.nl/en/about-tno/more-about-our-work/tno-working-paper-series/
FARM	ERS USDA	Sands et al. (2017)	

Table 1. Participating institutions and models (continued)

Model	Institution	Key reference	Website
Gdyn	GTAP	Ianchovichina and McDougall (2012)	www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3169
GTM	WTO	Aguiar et al. (2019)	
ICES	CMCC		www.cmcc.it/models/ices-intertemporal-computable-equilibrium-system
IGEM	Dale Jorgenson Associates	Jorgenson et al. (2013)	www.igem.insightworks.com/
IMACLIM	CIRED	Waisman et al. (2012)	link.springer.com/article/10.1007/s10584-011-0387-z
JRC-GEM-E3	EC JRC	Capros et al. (2013)	ec.europa.eu/jrc/en/gem-e3/model
MAGNET-Thunen	Thűnen Institut		www.magnet-model.org/
MAGNET-WUR	WEcR	Woltjer et al. (2014)	www.magnet-model.org/
MIRAGE-e	CEPII	Fontagné et al. (2013)	wiki.mirage-model.eu
MIRAGRO DEP	IFPRI		www.agrodep.org/model/miragrodep-model
PACE	ZEW	Böhringer et al. (2002)	www.transust.org/models/pace/model_pace.htm
REMIND	PIK	Luderer et al. (2015)	www.pik-potsdam.de/research/sustainable-solutions/models/remind
SNOW	Statistics Norway	Bye et al. (2018), Rosnes et al. (2019)	www.ssb.no/en/
TEA	COPPE	Cunha et al. (2020)	bibliotecadigital.fgv.br/dspace/handle/10438/28756
WegCenter CGE	Wegener Center, Uni. Graz	Mayer et al. (2017)	wegcenter.uni-graz.at/de/

6. A research agenda for baselines in CGE models

The papers in this special issue collectively provide guidance for modellers seeking to construct long-term baseline projections using a CGE model. It also allows users of CGE model analysis to better evaluate the strengths and weaknesses adopted in the analysis, and how the baseline underlying the analysis compares to other baseline scenarios presented in the literature.

The comparison exercise of modelling features that fed into this special issue leads to a number of recommendations for future CGE modelling, and especially for the CGE modelling community at large. First, it would be highly valuable to follow up the knowledge created here with a multi-model quantitative intercomparison exercise. By creating a harmonised set of scenarios and running these with a large set of CGE models, more in-depth insights can be gained on the main drivers of CGE baselines. Currently, it is very hard to evaluate what drives the differences between various model scenarios. The papers in this special issue provide a first step towards better understanding, but the key insights tend to be qualitative rather than quantitative. A proper model comparison exercise is, however, costly. There is a need to follow up the qualitative knowledge generated here by a quantitative model comparison exercise focusing on key economic parameters and specifications, including closure rules, capital accumulation and savings, and the role of sectoral and regional aggregation. It would also be desirable to include as many relevant CGE models as possible, preferably from a wide set of countries and institutions.

Secondly, it would be useful to better document existing CGE modelling baseline scenarios and the key assumptions underlying the numerical projections. The supplementary information file accompanying this paper provides an overview of some commonly used sources for calibrating dynamic trends in CGE models. One potential improvement would be to create an on-line space for modelling teams to contribute to a "model wiki" that contains the main model features, and link that to an online inventory of recent baseline projections.[2] The GTAP website could be a place to store this. A common pitfall in setting up such an information database is that it is typically hard to maintain the database and ensure the information provided is not outdated. Publishing baselines in more structured fashion in academic journals may be therefore have advantages, if the journal allows for articles focusing on baselines (see below). There is however a risk of herding behavior – that is the gravitation to a single, widely used set of assumptions and results which might unnecessarily limit the range of baselines.

The third recommendation builds on the combination of the first two: it would be extremely useful to improve the categorization of baseline scenarios. Once the

[2] See, for example,. https://www.iamcdocumentation.eu/index.php/IAMC_wiki for an example of such an online database.

key information for different existing baseline scenarios is available, broad categories of scenarios can be constructed, analogous to the SSP scenarios discussed in Section 2. By constructing a (multi-dimensional) matrix of baseline scenarios, future baselines can be classified and thus properly interpreted with much great ease and accuracy. The model comparison exercise could identify whether it is possible and useful to create such clusters of baseline scenarios, and whether common qualitative "storylines" to describe the different clusters can be found.

A fourth recommendation is to identify opportunities for publishing major new baselines in peer-reviewed journals, as has been done for the SSPs (O'Neil et al., 2014) . The peer-review publishing process provides a layer of confidence that the scenario is state-of-the-art that is useful for modellers that want to use an existing baseline as the basis for their own modelling analysis. In the past, this has proven to be difficult, not least because publishing a baseline requires sharing a large amount of information. As more journals allow supplementary information to be provided electronically, this barrier becomes much smaller. The establishment of the *Journal of Global Economic Analysis* (JGEA) has been very helpful to achieve this objective, as has been the inclusion of a special issue on CGE baselines. It is also highly welcome that JGEA has established an 'Updates' section that modelling teams could use to publish updates to baselines previously published in JGEA. This can provide modellers the incentives to carefully document baseline projections, and provide updates in a timely fashion, which is virtually impossible elsewhere.

Fifth, there are fundamental differences between short-term and long-term responses to shocks to the economic system, and dynamic CGE models can improve the way they differentiate these two elements. Furthermore, better understanding is needed on how short-term economic growth and structural transformation affect long-term trends in the economy, including for capital accumulation and technology development. Better integration of fiscal and financial aspects of the economy would also be important.

Last, but certainly not least, baseline projections are only as good as the assumptions that go into them. There is a constant need to improve model assumptions; better econometric estimations of key model parameters, such as elasticities of substitution and transformation, and the parameters that drive dynamic behaviour over time, including income elasticities, all require sound empirical foundations. The quantitative model comparison exercise suggested above should be able to identify the main research priorities in this respect. Better input-output tables for developing countries, and especially African economies, is also a key priority here, especially given the macroeconomic projections that suggest relatively fast growth and fast structural transformation in these less developed countries.

These recommendations notwithstanding, the papers in this special issue provide a detailed overview of the current state of long-term CGE baseline modelling, and should be helpful for both CGE modellers and the people that use the results of dynamic CGE analysis. The wealth of information provided in these papers should allow for higher quality CGE modelling analysis and contribute to improved quantitative policy advice.

To support the recommendations in this paper, researchers that produce global dynamic economic projections using CGE models are invited to contact the authors of this paper at CGEBaselines@purdue.edu to share key information on their model and the baselines they produce. Emails from interested researchers should include the following information: (1) model name, (2) the institution that owns the model, (3) a contact person and email address for each model, (4) the model's website (if applicable), (5) a published paper describing the model, and (6) a paper or website describing the latest baseline. Collecting this information in a crucial first step in inventorying recently published CGE baselines, conducting a quantitative model intercomparison exercise, and setting up a model wiki. Progress on this project can be followed at www.gtap.org/CGEBaselines .

Acknowledgements

The paper has benefited from valuable inputs and comments by the various modelling teams and the participants of the joint GTAP-OECD workshop of January 2018.

The views expressed are purely those of the authors. RD notes that this paper does not necessarily represent the views of the OECD or its member countries. BS notes that the views expressed may not in any circumstances be regarded as stating an official position of the European Commission.

Special thanks to Eddy Bekkers, Jean Chateau, Ruth Delzeit, Taran Faehn, Jean Fouré, Mun Ho and Matthias Weitzel for constructive feedback on earlier drafts.

References

Aguiar, A., Chepeliev, M., Corong, E., McDougall, R., & van der Mensbrugghe, D. 2019. "The GTAP Data Base: Version 10".*Journal of Global Economic Analysis*, 4(1), 1-27. doi: 10.21642/JGEA.040101AF

Aguiar, A., E. Corong, D. van der Mensbrugghe, E. Bekkers, R. Koopman and R. The. 2019, "The WTO Global Trade Model: Technical documentation." *WTO Staff Working Paper ERSD-2019-10.*

Aguiar, A., Narayanan, B., & McDougall, R. 2016. "An Overview of the GTAP 9 Data Base".*Journal of Global Economic Analysis*, 1(1), 181-208. doi: 10.21642/JGEA.010103AF

Ballard, C.L. and L.H. Goulder. 1985. "Consumption taxes, foresight, and welfare: a computable general equilibrium analysis", in J. Piggott and J. Whalley (eds), *New Developments in Applied Equilibrium Analysis*, Cambridge: Cambridge University Press, pp. 253-82.

Barro, R.J. and X. Sala-i-Martin. 1995. *Economic Growth*, New York: McGraw-Hill.

Böhringer, C., A. Löschel, and A. Rohde. 2002. *PACE-Policy analysis based on computable equilibrium*. In: Forum für Energiemodelle und Energiewirtschaftliche Systemanalysen in Deutschland, Energiemodelle zum Kernenergieausstieg in Deutschland, Effekte und Wirkungen eines Verzichts auf Strom aus Kernkraftwerken, Umwelt und Ökonomie Bd (Vol. 34, pp. 436-450).

Britz, W. and R. Roson. 2019. "G-RDEM: A GTAP-based recursive dynamic CGE model for long-term baseline generation and analysis", *Journal of Global Economic Analysis* 4(1), pp 50-96.

Bulavskaya, T., J. Hu, S. Moghayer and F. Reynes. 2016. *EXIOMOD 2.0: EXtended Input-Output MODel. A full description and applications*. doi: 10.13140/RG.2.2.16186.80321.

Bye, B., T. Fæhn, and O. Rosnes. 2018. "Residential energy efficiency policies: costs, emissions and rebound effects." *Energy*, 143: 191-201. doi:10.1016/j.energy.2017.10.103

Calzadilla, A., R. Delzeit, amd G. Klepper. 2012. "Assessing the Effects of Biofuel Quotas on Agricultural Markets" In *World Scientific Reference on Natural Resources and Environmental Policy in the Era of Global Climate Change*, edited by. R.A Matthew et al.. Singapore: World Scientific, Volume 3, 399–442.

Capros, P., D. van Regemorter, L. Paroussos and P. Karkatsoulis. 2013. *GEM-E3 model documentation*. JRC Scientific and Policy Reports, 26034.

Chappui, T. and T. Walmsley. 2011. "Projections for world CGE model baselines", *GTAP Research Memorandum* 22.

Chateau, J.,R. Dellink and E. Lanzi. 2014. "An Overview of the OECD ENV-Linkages Model: Version 3",*OECD Environment Working Papers* 65, Paris.

Chaudhuri, P. 1989. *The Economic Theory of Growth*, New York: Harvester Wheatsheaf.

Chen, Y.-H.H., S. Paltsev, J. Reilly, J. Morris, V. Karplus, A. Gurgel, N. Winchester, P. Kishimoto, E. Blanc, M. Babiker. 2017. *The MIT Economic Projection and Policy Analysis (EPPA) Model: Version 5*.

Crespo Cuaresma, J. 2017."Income projections for climate change research: A framework based on human capital dynamics", *Global Environmental Change* 42, pp 226-236.

Cunha, B. S. L., R. Garaffa and A. C. Gurgel. 2020. "TEA Model documentation", *FGV EESP – FGVAGRO n.001. Working Paper Series 520.* São Paulo, Brazil.

Dellink, R. 2005. *Modelling the Costs of Environmental Policy*, Cheltenham: Edward Elgar.

Dellink, R., J. Chateau, E. Lanzi and B. Magné. 2017."Long-term economic growth projections in the Shared Socioeconomic Pathways", *Global Environmental Change* 42, pp 200-214.

Dixon, P. and M. Rimmer. 2005. "Validating a detailed, dynamic CGE model of the USA", *The Economic Record* 86, pp. 22-34.

Fontagné, L., Fouré, J. and M.P. Ramos. 2013. "MIRAGE-e: A General Equilibrium Long-term Path of the World Economy" *CEPII Working Paper* N°2013-39, December.

Fujimori S, Hasegawa T, Masui T, Takahashi K, Herran DS, Dai H, et al. 2017a. "SSP3: AIM implementation of Shared Socioeconomic Pathways", *Global Environmental Change* 42: 268-283.

Fujimori S, Masui T, Matsuoka Y. 2017b. "AIM/CGE V2.0 model formula". In: Fujimori S, Kainuma M, Masui T (eds). *Post-2020 Climate Action: Global and Asian Perspective*. Springer, pp 201-303.

Ginsburgh, V. and M.A. Keyzer. 1997. *The Structure of Applied General Equilibrium Models*, Cambridge, MA: MIT Press.

Harrison, G.W., S.E. Hougaard Jensen, L. Haagen Pedersen and T.F. Rutherford (eds). 2000. *Using Dynamic General Equilibrium Models for Policy Analysis*, Amsterdam: North-Holland.

Ianchovichina, E. and R. McDougall. 2012. "Theoretical Structure of Dynamic GTAP", in: E. Ianchovichina and T. Walmsley (eds. *Dynamic Modeling and Applications in Global Economic Analysis,* Cambridge University Press

Ivanova, O., A. Kancs and M. Thissen. 2019. "EU Economic Modelling System: Assessment of the European Institute of Innovation and Technology (EIT) Investments in Innovation and Human Capital", *JRC Technical Report*, doi: 10.2791/184008.

Jorgenson, D., R. Goettle, M. Ho, P. Wilcoxen. 2013. *Double Dividend: Environmental Taxes and Fiscal Reform in the United States*, Cambridge: The MIT Press.

Klepper, G., S. Peterson, and K. Springer 2003. "DART97: A description of the multi-regional, multi-sectoral trade model for the analysis of climate policies", *Kiel Working Paper* No. 1149.

Leimbach, M., E. Kriegler, N. Roming, J. Schwanitz. 2017. 'Future growth patterns of world regions – A GDP scenario approach' , *Global Environmental Change* 42, pp. 215-225.

Luderer, G., M. Leimbach, N. Bauer, E. Kriegler, L. Baumstark, C. Bertram, A. Giannousakis, et al. 2015. "Description of the REMIND Model (Version 1.6)." *SSRN Scholarly Paper*. Rochester, NY: Social Science Research Network, November 30, 2015. https://papers.ssrn.com/abstract=2697070.

Mayer, J., G. Bachner, K. Steininger. 2017. "Macro-economic implications of switching to process-emission-free iron and steel production in Europe", *Graz Economic Papers*.

McKibbin, W.J. and P.J. Wilcoxen. 1998. "The theoretical and empirical structure of the G-Cubed model", *Economic Modelling* 16, pp. 123-148.

Nelson, G. C., Valin, H., Sands, R. D., Havlik, P., Ahammad, H., Deryng, D., Elliott, J., Fujimori, S., Heyhoe, E., Kyle, P., von Lampe, M., Lotze-Campen, H., Mason d'Croz, D., van Meijl, H., van der Mensbrugghe, D., Müller, C., Popp, A., Robertson, R., Robinson, S., Schmid, E., Schmitz, C., Tabeau, A., Willenbockel, D. 2014. "Climate change effects on agriculture: Economic responses to biophysical shocks", *PNAS* 111, 9, 3274-3279.

O'Neill, B.C., Kriegler, E., Riahi, K.et al. "A new scenario framework for climate change research: the concept of shared socioeconomic pathways".*Climatic Change* 122,387–400 (2014). https://doi.org/10.1007/s10584-013-0905-2

Rey, L., K. Wojtowicz, M. Tamba, T. Vandyck, M. Weitzel, B. Saveyn and U. Temursho. 2018. *Global macroeconomic balances for mid-century climate analyses*, EUR 29490 EN, Publications Office of the European Union, Luxembourg, 2018, doi: 10.2760/858469 (online), JRC113981.

Rey, L., K. Wojtowicz, B. Saveyn, M. Weitzel, T. Vandyck, M. Tamba, U. Temursho. 2019. *Baseline GECO 11/2018*. European Commission, Joint Research Centre (JRC) [Dataset] PID: data.europa.eu/89h/3ffc59a1-edff-491f-8894-3147d2202e42

Riahi, K. et al. 2017. "The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview", Global Environmental Change 42, pp 153-168.

Rosnes, O., B. Bye, and T. Fæhn. 2019. "The SNOW model – documentation of the Norwegian projection model for emissions and the economy (in Norwegian)", Documents 2019/1, Statistics Norway.

Ross, M.T. 2009. "Documentation of the Applied Dynamic Analysis of the Global Economy (ADAGE) Model," Research Triangle Park, NC: RTI International Working Paper 09_01.

Sands, R.D., S. Malcolm, S.A. Suttles and E. Marshall. 2017. *Dedicated Energy Crops and Competition for Agriculture Land*, ERR-223, U.S. Department of Agriculture, Economic Research Service, January 2017.

Shoven, J.B. and J. Whalley. 1992. *Applying General Equilibrium*, Cambridge: Cambridge University Press.

Sokolov, A. et al. 2005. "The MIT Integrated Global System Model (IGSM) Version 2: Model description and baseline evaluation", *MIT Joint Program of the Science and Policy of Global Change* Report 124, Cambridge.

Srinivasan, T.N. 1982. "General equilibrium theory, project evaluation and economic development", in M. Gersovitz, C.F. Diaz-Alejandro, G. Ranis and M.R. Rosenzweig (eds), *The Theory and Experience of Economic Development*, London: George Allen and Unwin, pp. 229-51.

van Tongeren, F., Koopman, R., Karingi, S., Reilly, J., & Francois, J. 2017. "Back to the Future: A 25-year Retrospective on GTAP and the Shaping of a New

Agenda". *Journal of Global Economic Analysis*, 2(2), 1-42. doi: 10.21642/JGEA.020201AF

Waisman, H., Guivarch, C., Grazi, F. et al. 2012. "The Imaclim-R model: infrastructures, technical inertia and the costs of low carbon futures under imperfect foresight", *Climatic Change* 101, 114-120. doi: 10.1007/s10584-011-0387-z

Weyant, J. et al. 2014. "The EMF27 study on global technology and climate policy strategies", *Climatic Change* 123, issue 3-4.

Winning, M., A. Calzadilla, R. Bleischwitz, V. Nechifor. 2017. "Towards a circular economy: insights based on the development of the global ENGAGE-materials model and evidence for the iron and steel industry",*International Economics and Economic Policy* 14 (3): 383-407.

Woltjer, G., M. Kuiper, A. Kavallari, H. van Meijl, J. Powell, M. Rutten, L. Shutes and A. Tabeau. 2014. *MAGNET Model, Module description*, The Hague : LEI Wageningen UR (Manual / LEI 14-57). edepot.wur.nl/310764

Appendix A. Summary of the OECD-GTAP workshop of January 2018

The workshop "Shaping long-term baselines with CGE models" was organised by the Center for Global Trade Analysis and hosted by the OECD's Trade & Agriculture and Environment Directorates. It was held on 24-26 January 2018 at OECD Headquarters. The meeting brought together around 80 experts on modelling economic baselines from 20 countries, representing 27 modelling teams. Many members of the GTAP Board participated,[3] as well as a number of other groups.

Since the early 1990s, there has been a large increase in the number of (mostly recursive) dynamic CGE models. Comparative assessment of results from dynamic CGE models is difficult without understanding the underlying drivers (even if some are harmonized to a basic set of exogenous drivers—such as GDP and population). The purpose of the workshop was not to harmonize the myriad of assumptions that underlie the building of a dynamic baseline, but to contrast and compare the different strategies across modelling teams, perhaps develop some best practices, and eventually develop proposals for a database and suite of practices that would enable different modelling teams to broadly emulate the behaviour of alternative models.

The first day of the workshop concentrated on methodologies for creating baseline projections, key model features of the models, and a session on macroeconomic drivers in baselines. The discussions on this day highlighted the need to exchange detailed information between modelling teams, which allows peer-learning. Suggestions were also made to develop a "matrix of scenario types" so that newly developed baseline scenarios can be quickly identified as belonging to a certain group of similar scenarios. It was also commonly felt that individual aspects of all models can be improved, but there is not much "low-hanging fruit" out there to improve all models quickly. One reason for slow development in the model specifications is that most teams have resources to do applied policy analysis, but hardly any resources for model maintenance and development. The last session of the day highlighted that various modelling teams would benefit from more detailed access to dedicated macroeconomic models that are used to provide context to the baseline projections (such as CEPII's MAGE model and the OECD's ENV-Growth).

The morning of the second day dealt with baseline inputs related to production factors and sectoral context, respectively. The group identified that for many model assumptions teams tend to agree on how the models could and should be calibrated, except for some contentious and fundamentally uncertain assumptions

[3] CEPII, EC/DG Trade, EC/JRC, FAO, University of Hohenheim, IFPRI, MIT, OECD, Thünen Institute, UNECA, US EPA, USDA, US ITC, Wageningen University, World Trade Institute and WTO.

on factor supply (not least labour supply) and the evolution of current account imbalances. It also became clear that soft-linking with other models, in particular partial equilibrium models that have detailed projections for a specific sector of the economy, is quite popular, but existing studies are often unclear about what is linked and how, which prevents peer-learning.

The afternoon of the second day was largely filled with break-out groups on agriculture, trade, and energy-environment issues. For each group, a number of more detailed insights were generated, but a few overarching conclusions were also drawn, not least that existing models tend to have advanced treatment of the issues that are directly related to the core of their research questions, e.g. detailed description of agricultural markets in models that focus on agricultural policy questions, but that relatively little effort is made to enhance representation of other policy domains, i.e. cross-fertilisation between agriculture, energy-environment and trade focused models.

The third day tackled the projections of structural change, as well as issues with harmonising the reporting of model outputs and validation of models. The discussions highlighted that the empirical evidence base for calibrating efficiency improvements and structural shifts in the economy tends to be rather weak, especially at a global level. Therefore it is important that models engage in cross-model comparison exercises, to understand how plausible specific model assumptions are. One key aspect of that is to understand in detail what model outputs represent; this can at least partially be achieved by setting up harmonised reporting templates for models to fill in. The session on validation highlighted that validation may not always be possible or even wanted (as these models don't do forecasting, nor are they representing hard scientific laws), but to maintain the credibility of modelling exercises efforts should be made to look at validation of model assumptions and projections. It is clear that no group can do a full validation exercise on its own, but if many teams each perform partial validation exercises, the modelling community as a whole can learn a lot about the validity of the models that are used.

The facilitators and other workshop participants identified a number of general main insights from the workshop:

- Teams want to intensify the possibilities to learn from each other, and to achieve this more detailed information should be shared between groups. The community would benefit from more standardised ways of exchanging numerical information.
- Developing a checklist of indicators and stylised facts is widely supported and seen as an important next step in the intensification of information exchange.
- Groups could learn from each other's expertise, for instance in identifying a minimum model specification that emulates the richer insights from dedicated models.

- Information exchange can also help to ensure consistency, which is important for comparing results of different models.
- Modelling reports and articles should generally make a bigger effort in explaining the baseline calibration process, how baseline assumptions affect model results, and be explicit in constraints faced in calibration of baselines.
- The final session was devoted to a discussion on how to move forward. It identified the following steps that can be taken:
- Develop a “wiki of CGE models”; many teams have already summarised their main information in a Powerpoint presentation before the workshop, and this could be transformed into ID-sheets for each model with brief description of the key model features.
- Develop a survey that can identify which indicators the different teams want to compare across models, and what plausible values for each of these are.
- Create a repository of model baselines (with information on key assumptions). While there are constraints in terms of available resources and institutional constraints, a first step would be to exchange a limited set of information between the participating teams, without making anything publicly available.
- Explore the possibility for summarising the outcomes of the workshop in a series of technical papers, potentially issued as a special issue in a journal.
- Many groups expressed interest in a follow-up workshop on numerical baseline comparison, focusing on macroeconomics and SSP2-type baseline scenarios.

Appendix B. Detailed overview of participating models

Model	Institution
Applied Dynamic Analysis of the Global Economy (ADAGE)	United States Environmental Protection Agency (US-EPA)
Asia-Pacific Integrated Model (AIM)	National Institute for Environmental Studies (NIES)
Dynamic Applied Regional Trade Model (DART)	Kiel University
Multi-Sector Multi-Regional Model (EC-MSMR)	Environment and Climate Change (ECC) Canada
Environmental Global Applied General Equilibrium (ENGAGE)	University College London (UCL)
Environmental Impact and Sustainability Applied General Equilibrium (Envisage)	Global Trade Analysis Project (GTAP)
Environment Linkages (ENV-Linkages)	Organization for Economic Co-operation and Development (OECD)
Emissions Prediction and Policy Analysis (EPPA)	Massachusetts Institute of Technology (MIT)
European Economic Modelling System (EU-EMS)	Planbureau voor de Leefomgeving (PBL)
Extended Input-Output Model (EXIOMOD)	Netherlands Organization for Applied Scientific Research TNO
Future Agricultural Resources Model (FARM)	Economic Research Service, United States Department of Agriculture (ERS-USDA)
Dynamic GTAP Model (GDyn)	Global Trade Analysis Project (GTAP)
Global Trade Model (GTM)	World Trade Organization (WTO)
Intertemporal Computable Equilibrium System (ICES)	Euro-Med. Center on Climate Change (CMCC)
Intertemporal General Equilibrium Model (IGEM)	Dale Jorgenson Associates
Impact Assessment of Climate Policies (IMACLIM)	Centre International de Recherche sur l'Environnement et le Développement (CIRED)
General Equilibrium Model for Economy – Energy – Environment (JRC-GEM-E3)	European Commission – Joint Research Centre (EC-JRC)
Modular Applied General Equilibrium Tool (MAGNET-Thünen)	Thünen Institut
Modular Applied General Equilibrium Tool (MAGNET-WUR)	Wageningen Economic Research (WEcR)

Model	Institution
Modelling International Relationships in Applied General Equilibrium (MIRAGE-e)	Centre d'Etudes Prospectives et d'Informations Internationales (CEPII)
Modelling International Relationships in Applied General Equilibrium for African Growth and Development Policy Modeling Consortium (MIRAGRODEP)	International Food Policy Research Institute (IFPRI)
Policy Analysis based on Computable Equilibrium (PACE)	Centre for European Economic Research (ZEW)
Regional Model of Investments and Development (REMIND)	Potsdam Institute for Climate Impact Research (PIK)
Statistics Norway's World Model (SNoW)	Statistics Norway
Total-Economy Integrated Assessment Model (TEA)	Technology Center of the Federal University of Rio de Janeiro (COPPE)
Wegener Center Computable General Equilibrium (WegCenter CGE)	Wegener Center, University of Graz