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Expert consultation workshop on transboundary effects

D7.3

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Explore sustainable European futures

Expert consultation workshop on transboundary effects

D7.3

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Short Description
This deliverable describes presentations, discussions and lessons learnt during the EU Calculator Expert consultation workshop on transboundary effects, held on the 22nd of November, 2018. The three main topics of discussions were the representative scenarios to be formulated and simulated in the transboundary effect module, the exploitation of the trade results in the Pathway Explorer, and CGE implications of the macro-level development of trade and globalization.

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Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgment of previously published material and of the work of others has been made through appropriate citation, quotation or both.

EUCalc policy of personal data protection in regard to the workshop

EUCalc defined the procedures in order to reply to ethical requirements in Deliverable 12.1 (Ethics requirements – procedures and criteria to identify research participants in EUCalc – H – Requirements No. 1). All procedures in relation to the co-design process, in particular the stakeholder mapping, the implementation of the workshops and the follow-up of the workshops, follow these procedures. The informed consent procedure in relation to the workshops is based on D9.2 "Stakeholder mapping" and D9.4 "Method for implementation of EUCalc co-design process". The originals of the signed consent forms are stored at the coordinators' premises without possibility of access of externals. Scans of the informed consent forms are stored on the internal EUCalc file storing system.

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Glossary

BAU: Business As Usual
CGE: Computable General Equilibrium
EU: European Union
GDP: Gross Domestic Product
GHG: Greenhouse Gas
GTAP: Global Trade Analysis Project
MS: Member State
ROW: Rest Of the World
SSP: Shared Socio-economic Pathway
TFP: Total Factor Productivity
UCPH: University Of Copenhagen
WP: Work Package

1 Executive summary

The representation of transboundary effects within the EUCalc was discussed at an expert engagement workshop held in Brussels on 22nd November 2018. The workshop was attended by the EUCalc team responsible for the transboundary module and experts from a range of institutions representing the views of both governmental and non-governmental research and policy organizations.

The workshop started with a series of presentations by the EUCalc team. Professor Jeremy Woods from Imperial College London (ICL) and Ana Rankovic from SEE Change Net gave introductory presentations on the logic of the project and the concept of the EUCalc model. Professor Wusheng Yu from University of Copenhagen presented the results of the preliminary research activities under the transboundary module, as well as associated challenges, to participating experts. This introduction was then followed by three discussion sessions focusing respectively on three sets of questions prepared by the EUCalc team. In these sessions, the experts were invited to provide their insights, suggestions and comments to help shaping the modeling approach and overcome modeling challenges.

In general, the workshop participants recognize the uniqueness of the EUCalc modeling approach and its potential contributions to the EU decarbonization debates. The major challenges associated with modeling the transboundary effects among the European Union Member States (EU MS)and between the EU and the rest of the world (ROW) using "bottom-up" inputs from the rest of the EUCalc model, as presented at the workshop, are clearly understood by the participants. The discussions confirmed the complex nature of the modeling choices that the EUCalc team will have to make in the modeling work. The experts were supportive of the modeling approach proposed by the EUCalc team while offering many insightful suggestions for tackling the modeling challenges identified.

More specifically, on the questions concerning representative scenarios to be formulated and simulated in the transboundary effect module, the experts agree with the team's general approach to only select and model relevant and representative EUCalc pathways. On the three sets of scenarios that we proposed in the pre-reading material and presented at the workshop, the experts emphasized the need to pay attention to the scenarios that are likely to be used by users. One suggestion is to aggregate along the member state dimension and focus more on sectoral decarbonization differences. This effectively further reduces the number of scenarios to be modeled. Another suggestion is to model an even smaller set of scenarios and list them as pre-defined pathways in the EUCalc pathway explorer. In general, the experts cautioned against the ambition to model too many scenarios in a complex CGE model. The idea of using the selected representative scenarios to "envelope" or represent the full set of EUCalc pathways are supported by the participants; however, the experts were quite cautious about the necessity and the feasibility to make "interpolations" to approximate the non-modeled scenarios.

On the questions regarding the exploitation of the results, the participants offered insightful suggestions and recommendations. They agreed with the need to further process the transboundary results into key indicators to facilitate the display of such results. Among the suggested indicators are the ones that can be derived from the modeling results, such as changes in trade balances and carbon leakages through trade by country and at EU level, and possibly with further breakdowns by key sectors. Other suggested indicators were also mentioned, such as air pollutants and labor market related issues, which are out of the scope of the transboundary module but are dealt with in other EUCalc modules. Moreover, suggestions were also provided on allowing users to dig deeper into the results.

The last set of the questions deals with both the macro level development of trade and globalization and the underlying modeling instruments of these macro trends, as reflected in the design of the baseline and the selected scenarios. Here, there is a broad support for the baseline compilation and implementation approach documented in D7.1. On the specific modeling issues that we brought for discussion at the workshop (e.g. long term trade policy trends, trade to GDP ratio, size of trade elasticities, sectoral productivity growth, fossil fuels prices, and land supply), it appears that modelers generally agree to a set of "best practices" (which are in fact being used by the EUCalc team) but they indicated that the exact model implementations do differ across models and modeling teams. In any case, the specific suggestions gathered in this session pointed us to additional data, parameters and assumptions that can either be used or cited as further references in the modeling work.

Overall, this workshop was an important milestone in the research and design of the transboundary module. The experts' inputs are being assessed and used for the improvement of the EUCalc tool. The project will continue to interact with the experts, those who attended the workshop as well as those who, although unable to attend the workshop, expressed their interest to be involved.

2 Introduction

With the aim of providing decision makers with accessible climate and energy modelling solutions, the EUCalc project will create a state-of-the-art model for analyzing trade-offs and pathways towards a sustainable and low-carbon European future. An associated web-tool, the Transition Pathways Explorer, will provide instant results from the European Calculator model runs and allow users to explore options for reducing GHG emissions from now to 2050, as well as to see the consequences of these choices on multiple sustainability issues in real-time.

The EUCalc addresses multi-dimensional and inter-disciplinary issues that requires a wide range of expertise to develop the tool. In this context, the EUCalc embeds a co-design process with stakeholders who are leading experts in their field. The co-design process is organized through a series of workshops, one for each main module (see Figure 1). Through this approach, external experts are part of the designing process which enables them to shape and calibrate the EUCalc tool by helping co-design the determinants and the scope of the scenarios.

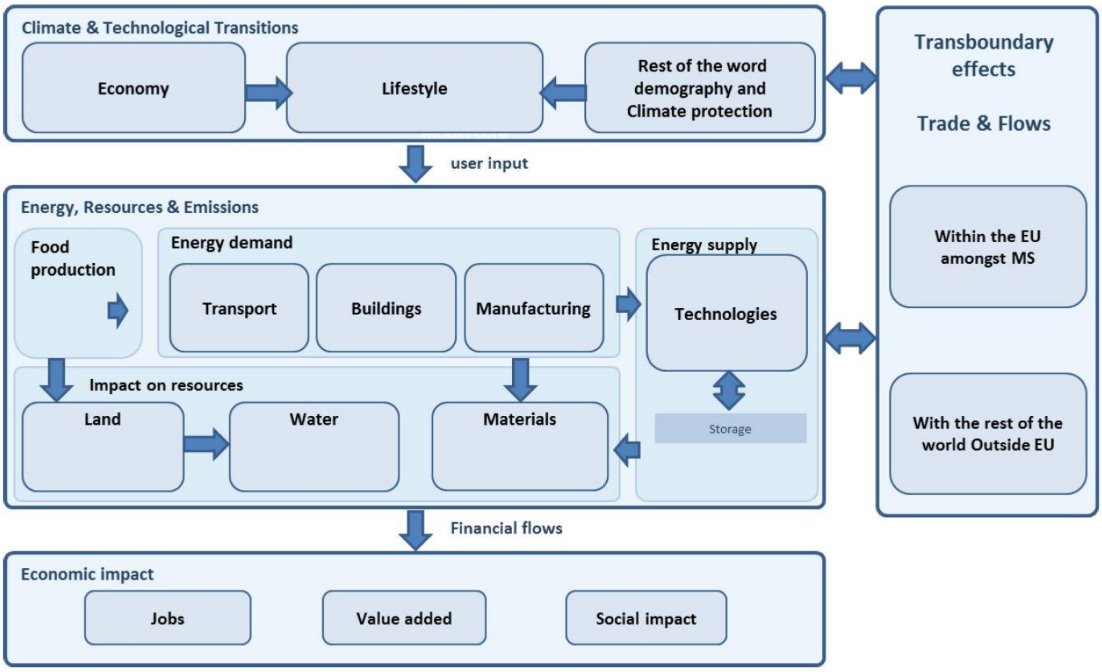

Fig. 1 Modular structure of the European Calculator Model

The University of Copenhagen (UCPH) is leading the work package on *"Transboundary Effects and Trade flows"* ("WP7" hereafter) of the EUCalc project, in collaboration with PIK-Potsdam, Imperial College London, Climact, Climate Media Factory, T6ECO, SEE Change Net and TU Delft.

Within the broader scope of the Calculator, the WP7 aims at quantifying the transboundary effects on intra- and extra-EU trade flows of alternative EUCalc pathways by using a computable general equilibrium (CGE) modelling framework. The simulated transboundary effects will inform EUCalc users of likely future economic dependencies inside the EU as well as between the EU and the rest of the world due to the EU's decarbonization efforts.

The EUCalc expert engagement workshop devoted to "*Transboundary effects of EU decarbonization pathways*" was held in Brussels, at the European Climate Foundation, on 22nd November 2018.

The UCPH team identified beforehand several challenges that have surfaced during the research and design phase of the transboundary module. In order to facilitate the workshop deliberations, a pre-reading document was provided to participants in advance, including preliminary research results and information about modelling approach and methodology (Section 3.2).

Ten experts from international organizations, public and private sector with relevant expert background and experience to critic as well as to provide evidence-based input regarding the transboundary effects and trade flows on both European and global scale, attended and contributed to the workshop discussions. Participants list is annexed to this report (Section 6.1)

The workshop was professionally designed and facilitated. It was composed of the three distinct components:

- Introduction of the EUCalc project in a plenary scene setting (Section 3.1);
- Presentation of the specific components of the Transboundary module (Section 3.2);
- Break-out group discussions in which experts reviewed and reported back on key questions and topics (Section 3.3).

2.1 Objectives of the expert consultation

The "*Transboundary effects of EU decarbonization pathways*" workshop introduced the philosophy of the EUCalc tool to a cross-section of experts. It also presented preliminary research results and assumptions of the EUCalc's transboundary module. The workshop provided a venue for experts to critically examine, validate and advise on the underlying methodology.

Participants were invited to work in small groups and to collect their thoughts individually and collectively on each of the following discussion areas that constitute some of the challenges faced by WP7 in the modelling work:

- The most relevant and representative EUCalc user-defined pathways to be simulated in a CGE model for generating the transboundary effects, including the sets of potential scenarios proposed by the EUCalc team and/or any other important/relevant scenarios.
- The ways to present transboundary effects in the EUCalc (e.g. as the trade matrix itself or in terms of key indicators) including the question of what key transboundary effects, at what sectoral aggregation level and how they should be presented in EUCalc
- The long-run relationship between GDP growth and trade expansion, the size of key parameters such as trade elasticities (e.g. Armington elasticities), the use of differential sectoral productivity growth pattern to generate expected structural changes, the treatment of land and other natural resource supply, and the representation of changing energy technologies in a trade-focused CGE model. These questions can be more generally summarized in a discussion on recent setbacks in globalization and global cooperation, their implications on long run trade development and decarbonization efforts, as well as the EU's future position and role in global trade and global decarbonization efforts.

3 Workshop description

3.1 Setting the scene

The expert consultation workshop was opened with a welcome speech given by Professor Wusheng Yu from the University of Copenhagen, the institution organizing the workshop. Professor Jeremy Woods from the Imperial College London gave an overview presentation on the EUCalc project. He outlined the history, philosophy and the logic of the Calculator's approach. By using the Global Calculator as a proxy, he demonstrated how it allows users, particularly decision makers, to interactively navigate, use and visualize the results of each selected scenario. He was then followed by Ana Rankovic from SEE Change Net, who highlighted the role and importance of the co-design process for the EUCalc development. Their introductory presentations were followed by an overview of the transboundary module.

3.2 Description of the transboundary module of the European Calculator

In his introductory presentation, Professor Wusheng Yu focused on the specific features of the transboundary module (e.g. modelling approach, scope etc.), while also highlighting several challenges that have surfaced during the design phase of the module.

Within the EUCalc project, transboundary flows refer to the trade of goods and services amongst the EU MS, as well as between the EU and the Rest of the World (ROW). As the envisioned decarbonization pathways impose changes in both demand and supply for a number of sectors (e.g. energy, materials, food, transport), levels and structures of production and consumptions at sectoral and country levels would also be altered. This in turn would change the internal and external economic dependences concerning the EU MS at sectoral levels and lead to changed trade patterns. Furthermore, as transboundary flows of goods and services embody energy consumption and GHG emissions, projecting transboundary flows is therefore an important consideration in evaluating the options and tradeoffs of EU decarbonization pathways.

3.2.1 Modelling approach

Modeling the transboundary effects mandates the use of an economic modeling system that takes into consideration not only inter-sectoral linkages such as the input-output linkages connecting raw materials and fossil fuels to final outputs, but also linkages through the competition/allocation of available economic resources such as labor and capital. Further, EU MS and the rest of the world must also be connected in the model such that imbalances between demand and supply at sectoral levels for each country can be accounted for via transboundary trade flows. Essentially, this points to the use of a global computable general equilibrium (CGE) model focused on trade linkages. In fact, CGE models are a typical tool for empirical analysis of distributional and welfare impact of different policies (Wing, 2004, Burfisher, 2011). More generally, they can be used to measure the result of shocks to an economic system (i.e. computable), encompassing simultaneously all economic activities (consumption, production, employment, taxes, savings, trade etc.) and the linkages among them (i.e. general), in an economy where at a given set of prices all agents are satisfied (i.e. equilibrium) (Burfisher, 2011). To analyze the trade and transboundary effects of EUCalc decarbonization pathways, WP7 adopts a modified version of the GTAP-E model (Burniaux and Truong, 2002, McDougall and Golub, 2007), which is the energy-environmental version of the GTAP model (Hertel et al., 1997). The GTAP model is generally considered as a standard CGE model. GTAP's expansive country coverage and its general equilibrium modelling structure on sectoral and trade linkages within and across countries complement the scope of the EUCalc as it allows for simulating the transboundary effects of alternative EUCalc pathways under various lever settings.

Substantive research efforts in WP7 include:

- Constructing baseline projections based on the GTAP9 database (Aguiar et al., 2016) at its sectoral and country classifications to 2050, to coincide with the 2050 timeline envisioned in other WPs of the EUCalc;
- Modifying the structure of the GTAP-E core model to accommodate the sectoral coverages of other EUCalc WPs, including sectoral energy consumption and emissions;
- Designing an interface to facilitate the transformation of alternative sectoral EUCalc pathways as inputs into the specifically designed GTAP model for simulating the transboundary effects;
- And simulating the alternative EUCalc pathways as model scenarios to generate the transboundary effects to be included in the EUCalc pathway explorer.

Thus, this WP interacts with WPs 1-5 by using their results and with WP8 by supplying the transboundary effects as inputs.

3.3 Discussion & recommendations

The third and largest segment of the workshop was dedicated to eliciting input from experts.

In particular, the discussion focused mainly on the three following questions:

- *Representative scenarios:* What are the most important, relevant and representative user-defined EUCalc pathways to be simulated in the CGE model for generating the transboundary effects, particularly concerning the commonalities and deviations of decarbonization ambition levels across member states and sectors? Once selected, these representative scenarios will be used to form an "envelope" to approximate the full range of the virtually unlimited EUCalc user-defined decarbonization pathways.

- *Key transboundary effects:* What key transboundary effects (e.g. intra and extra-EU trade flows) should the model exercises focus on? At what sectoral aggregation level and for which key sectors should such results be computed? How should the simulated transboundary effects be presented in EUCalc (e.g. as the trade matrix itself or in terms of key indicators such as self-sufficiency ratio, trade dependency/exposure index, or other indicators)?

- *Modelling assumptions:* Is there a long-run relationship between GDP growth and trade expansion and, if so, how can such relationship be enforced in the CGE model? What is the "correct" range of key parameters such as trade elasticities (e.g. Armington elasticities)? In simulating scenarios of large structure changes, what are the reasonable assumptions regarding differential sectoral productivity growth patterns? In a trade-focused CGE model, how should long-run land and other natural resource supply be specified? And how can changing energy technologies be parsimoniously represented?

During the workshop, handouts and guiding questions were provided to help start the discussions (Section 6.3). The workshop also engaged the assistance of designated rapporteurs made up of members of the consortium.

The experts' inputs and suggestions in each discussion area are presented hereinafter.

3.3.1 Relevant and representative user-defined pathways in the EUCalc for generating the transboundary effects

EUCalc will generate billions of "instant" results, given the very large possibilities of combining its levers. This is not possible in GTAP, which requires precise calibration of the modifications to be imposed in the model and time to simulate the scenarios[1]. Owing to the size and computational complexities of the CGE model to be used, the trade module will focus on simulating the transboundary effects of a subset of the virtually unlimited user-defined decarbonization pathways to provide an "envelope" to approximate the full set of user-defined pathways.

Deliverable 7.2 (Baudry et al., 2018) lists potential scenarios to be simulated in GTAP. They can be divided into three categories:

- The first set will simulate scenarios with identical ambition levels in all sectors and countries (i.e. 4 scenarios deriving from the 4 lever settings);
- The second set will simulate different ambitions across the sectors, with sectoral ambition levels being kept the same across EU MS;
- The third set simulates scenarios with deviations by individual countries from the EU-wide ambition, i.e. each EU MS is assumed to deviate its level settings (uniform across sectors) from the common level setting assumed for all other MS in the core scenario.

It is possible that not all of these scenarios can be successfully computed, mainly because some particular pathways (e.g. those linked to ambition levels set at 3 or 4, i.e. very high ambitions) may represent a drastic departure from the current state of the economic system, for which the CGE model may not be able to find equilibrium solutions. The sectoral and regional aggregations play a fundamental role in obtaining coherent and reliable results from GTAP. For some small MS, the production and trade matrices in the GTAP database present values that are very close to zero. This increases drastically the risk of incurring in corner solutions, hindering the accuracy or even the solvability of the model. Therefore, the experts suggested to show a warning sign in the Transition Pathway Explorer whenever an user-defined EUCalc pathway cannot be simulated in GTAP.

The experts clearly understood these challenges and generally supported the pragmatic modeling approach presented at the workshop. They highlighted the trade-off between modeling the EU as a whole while at the same time increasing the sectoral granularity and modelling individual EU member states with a denser sectoral aggregation in the CGE model. An intermediate alternative was also proposed by some of the experts to aggregate some of the EU MS with either similar economic structures (e.g. Benelux, Baltic countries) or whose trade matrices are "too small" to be specifically modelled in the EUCalc context (e.g. Malta, Cyprus). The proposal to focus the modeling exercise on the sectoral differences (at an aggregated EU level) rather than at the individual MS level suggests to focus on the first and second sets of the proposed scenarios outlined above, rather than the third set where countries individually deviate from the EU-wide pathways.

Regarding the ambition in simulating 600+ scenarios in the CGE model, a number of potential complexities were raised by the modelers. In particular, modeling in GTAP technological breakthroughs (i.e. level settings 4, corresponding to the highest abatement ambition) can be challenging and misleading, as it implies major 'unforeseeable' changes in a sector having a spillover effect on the rest of the economy, and leading to major abrupt structural changes that are potentially inconsistent with the current economic structure.

The "envelope" approach to use a limited set of representative, important and relevant scenarios to represent the full set of possible EUCalc pathways was widely supported by

[1] Depending on the sectoral and regional aggregation and on a set of other parameters, it can take up to hours to compute a solution in GTAP

the modelers attending the workshop, as it offers the best balance between plausibility and exploring boundary conditions, in terms of ambitions and sectors involved. In fact, rather than computing all or most of the selected scenarios listed above to form an envelope for the full set of EUCalc pathways, some participants even proposed to only model a much smaller number of relevant ones and show them to the final EUCalc user as pre-defined pathways, in a fashion similar to the Global Calculator. These pre-defined pathways could be the EU's or individual countries' NDC targets and other relevant climate scenarios that are likely to be of interest to the users (however, the experts did not specify these other scenarios.

Two other suggestions not included in the proposed sets of scenarios were offered:

- The addition of scenarios measuring how different climate ambitions in ROW affect the carbon leakages of different EUCalc pathways;
- A "policy comparison" within the CGE model, where different instruments (e.g. carbon tax, cap and trade or "twist parameter"(Dixon and Rimmer, 2002)) are used to achieve the same pathways.

Both suggestions are highly relevant in the current current academic and political debates. However, the current scope of the EUCalc project prevent us from pursuing these suggestions.

3.3.2 Presentation of the transboundary effects in EUCalc

A single simulation in GTAP generates a substantial amount of trade-related results which, if not properly presented to the model users, may be difficult to read and use. This would hamper one of the objectives of EUCalc (i.e. accessibility) and would deprive EUCalc of one of its distinctive features from the existing family of Calculators, i.e. computing trade effects arising from different EU decarbonization pathways. Therefore, a practical way to effectively exploit the results derived from GTAP is to further process the results to obtain some indicators that may be meaningful for users and policymakers and are easy to present in the online EUCalc Pathway Explorer.

Acknowledging this, the experts were asked what key transboundary effects (e.g. intra and extra-EU trade flows) should the WP7 focus on, at what sectoral aggregation level and for which key sectors should such results be accessible, and how should the transboundary effects be presented in EUCalc (e.g. as the trade matrix itself or in terms of key indicators such as self-sufficiency ratio, trade dependency/exposure index, revealed comparative advantage index, etc.).

The identified key transboundary effects are the changes in the trade balances, both in monetary values and embedded GHG emissions. More precisely, the analysis of self-sufficiency in strategic sectors (e.g. emission-intensive sectors, food, fuels, materials, etc.) has been recognized as crucial, together with the accounting of the GHG content of the commodities traded.

Carbon leakage both inside and outside the EU has been suggested as a highly relevant issue. In order to achieve additional accuracy in observing whether a country is a net importer or net exporter of embodied emissions, it has been suggested to divide the ROW region into a few regions (e.g. USA, China, India, Japan, high income countries, low income countries). Aside from these suggestions, several experts also expressed wishes for additional results in the trade module, such as energy- and water-intensive commodities and even biodiversity, even though the experts considered this highly challenging for the timeframe of the EUCalc project. Some experts also mentioned labor market issues such as labor mobility and migration, issues are potentially related to the employment module of EUCalc.

The sectoral granularity, according to some participants, would ideally be at the lever level. However, according to most of the other contributors, this could be misleading for the user and is virtually impossible to model in detail in the CGE. The focus could then be on the sectors grouped according their emission intensities (sensible for presenting and highlighting the carbon leakages) and/or on sectors used in other climate-related modelling exercises (e.g. IPCC classification) and/or sectors as separated in policy decisions (NDC sectors, or ETS vs non-ETS sectors). A "magnifying glass" approach (i.e. providing interactive menus on the pathway explorer to allow users to dig deeper into the results) has been proposed by some experts, as it provides the user with both an overview on the main EUCalc sectors, at the same time allowing for analyzing more in detail each of the sectors.

Additionally to the transboundary flows both in monetary and GHG terms, a number of other proposals were presented, from 'simple' indexes as the net trade position intra- and extra-EU or emission shares to the less intuitive KAYA identity (Kaya and Yokoburi, 1997). Other inputs have been given in terms of the graphs to show, with a relatively general agreement on using maps at the regional level. It has also been proposed to offer a "bulk download" possibility (e.g. a .csv file) to allow the users to carry out their own calculation from the "raw" GTAP results. Finally, it was stressed that representation of uncertainty is of utmost importance and some sensitivity analysis of the key GTAP parameters could help in achieving this representation. However, given the large number of simulations to conduct, it is impractical to conduct sensitivity analysis for these simulations.

3.3.3 Modeling assumptions

Part of the efforts in WP7 are towards the construction of a baseline based on the GTAP9 database, as mentioned in section 3.2.

The purpose of the baseline construction is to establish a likely business-as-usual (BAU) scenario towards 2050, against which the transboundary effects of alternative EU decarbonization pathways can be simulated. In Deliverable 7.1 (Yu and Clora, 2018), we gathered annual GDP projections and the associated main drivers such as population, labor force (skilled and unskilled), capital stock, and total factor productivities for individual countries including all EU MS. After surveying several recent model-based projections that can be considered as BAU, i.e. various "reference" scenarios and Shared Socioeconomic Pathway 2 (SSP2)[2] projections, we selected the following sources:

- GDP: EU Reference Scenario 2016 (European Commission et al., 2016) and OECD-SSP2 (Dellink et al., 2017);
- Population: EUROSTAT, EU 2015 Ageing Report (European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2014, European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2015) and SSP2 projections for IIASA (Kc and Lutz, 2017);
- Labor force: EUROSTAT, EconMap2.4 (Fouré and Fontagné, 2016) and EU 2015 Ageing Report (European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2015). Total labor force is divided into skilled and unskilled, drawing from education projections obtained from Fouré and Fontagné (2016), which in turn are gathered from Kc and Lutz (2017);
- Capital stock: EconMap2.4 (Fouré and Fontagné, 2016);
- Total factor productivity (TFP): EconMap2.4 (Fouré and Fontagné, 2016) and EU 2015 Ageing Report (European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2015).

With these data, we used the GTAP-E model to project the world economy from 2011, which is the base year of the GTAP-E 9 database (Aguiar et al., 2016), to 2050. In this projection, we targeted population and labor force projections during the 2011-2050 period

[2] The Shared Socioeconomic Pathways describe alternative trends in the evolution of society and ecosystems from 2005 to 2100 at the world and regional levels. The SSPs are part of a framework that the climate change research community has adopted to facilitate the analysis of future climate impacts, vulnerabilities, adaptation, and mitigation. In SSP2, the world would undergo a transformation in which social, technological and economic trends do not deviate much from historical patterns observed over the past century.

by directly imposing shocks to the correspondent exogenous GTAP variables. To project GDP, we endogenized TFP in order to target the projected GDP levels. Additionally, we endogenized the total capital stock using the "Baldwin equation" (Francois and McDonald, 1996), opting for a fixed savings rate closure with capital accumulation.

In addition to implementing the macroeconomic projections, we also targeted the projected changes in fossil fuel prices (IEA, 2012, IEA, 2017) by endogenizing changes in the productivity of the oil, coal and gas sectors. Finally, we also assumed a 2 percentage points differential with respect to the regional TFP between the manufacturing sectors and other sectors.

When implementing the baseline, it is obvious that many other factors may also shape the world economy and the way the world economy is interconnected in the long term. For instance, different CGE modelling groups apply different approaches with respect to sectoral productivity differentials, trade openness and trade costs, aggregate land and natural resource supply, long-term income elasticities, and linkages between the economy and the environment. All these considerations may have non-trivial implications on the structure of the projected baseline.

With respect to inter-sectoral productivity differences, we followed an approach similar to the one suggested in Fouré and Fontagné (2018) and LINKAGE (Van der Mensbrugghe, 2005). The two studies assume 2 percentage points additional productivity change in manufacturing with respect to services and use exogenously defined TFP for agriculture. In our projection exercise, we assumed the manufacturing sectors' TFP to be 2 percentage points higher than the average regional TFP. Other studies, such as the WTO World Trade Report 2018 (WTO, 2018a), estimate econometrically these productivity differentials with respect to the average TFP in each region, based on databases such as EU KLEMS and OECD-STAN. There are also a few CGE models that use an array of differential sectoral productivities, in particular with respect to the relative TFP growth in agriculture. For example, Robinson et al. (2014) suggest that TFP growth in both developed and developing countries is highest in agriculture, followed by manufacturing and services.

In addition to inter-sectoral productivity differences, other major drivers of structural change are trends/assumptions on trade policies and globalization and trade-related parameters.

In long-run projections, current or historical trade policy trends are typically assumed. For example, Fouré and Fontagné (2018) adjust tariffs to their historical trend (2004-2011), using MacMap HS-6 CEPII ITC database. Given the recent setbacks in globalization and global cooperation, one may wonder whether there will be a need to modify our recent assumptions on trade policy trends or whether the recent setbacks are merely a transitory phenomenon that would not be persistent in the period of our projection.

Another important issue in long run projection of trade flows rests on the size of the trade elasticities. Thus far, we have been using the Armington elasticities[3] provided in the GTAP-E 9 database. However, given the major structural changes in the world economy, the estimation of correct Armington elasticities is crucial, as the standard ones could lead to unreasonable trade volumes for certain products among regions (Schuerenberg-Frosch, 2015). For example, if a sector-specific carbon tax is implemented, the high elasticity for gas could result in over-traded gas as it has lower emission intensities as compared to other fossil fuels (oil and coal). On the other hand, as EU countries are operating within an integrated market, the opposite argument for higher elasticities for intra-EU trade flows of many other products may be appropriate. Therefore, guidance on adopting appropriate trade elasticities was needed.

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[3]Armington elasticity: elasticity of substitution between imported products sourced from different exporting countries. It is based on the assumption made by Paul Armington in 1969 that products traded internationally are differentiated by countries of origin. Therefore, it governs the strength of the relative demand responses to relative international prices.

The assumptions regarding the trade-to-income elasticity are also essential for determining the aggregated global trade volume in 2050. Fouré and Fontagné (2018) calibrate the trade-to-income elasticity on historical data. However, this elasticity has been falling in recent years relative to its long-run trend (Hukkinen et al., 2016). Since carbon leakages are crucial within the EUCalc, the decision of exogenizing or endogenizing the trade-to-income ratio is of fundamental importance, as it will have a major impact on the final results. In some CGE models, the base assumption is a linear relationship between GDP growth and trade expansion, which nevertheless does not fit well with past observations (WTO, 2018b).

Moreover, reductions in trade costs are an important factor to take into account, in particular in the light of the importance of trade for the EUCalc. In the last decades, falling trade costs have been observed (OECD and WTO, 2015). Furthermore, the adoption of new transportation technologies and the opening of the Northern Sea Route due to melting ice caps may further reduce transportation costs in the future (Bekkers et al., 2018). Thus, whether or not efficiency gains in the global transportation sectors should be considered becomes a relevant question.

An additional issue, connected to the expected increase in food demand towards 2050, is about the long-run supply of aggregated land. Currently, in GTAP total land supply is fixed at the regional level. However, rising land rents may cause additional land to be brought under cultivation, even though the price elasticity of land supply is estimated to be very low (Renwick et al., 2013, Philippidis et al., 2017). The finite amount of land (and the impossibility of "producing an extra unit") may be solved by introducing a logistic function for land supply in GTAP, as e.g. in ENVISAGE v10[4](van der Mensbrugghe, 2018).

Given the multifaceted complexities of such discussions, the participants were divided in two groups looking into them from different angles. The first group focused on the general macro-trends, whereas the second focused on how these trends should be approached from a CGE model perspective.

3.3.3.1 Macro-trends

The core of this dialogue was formed by the envisioned future trade patterns, from a wide political-economic perspective, rather than the CGE modeling viewpoint presented in section 3.3.3.2. In particular, trade policy trends and the role of the EU in global trade and global decarbonization efforts were discussed.

Most of the opinions pointed out that, even though we are currently experiencing hindrances in globalization and global cooperation, the EU position has always been prone to support open trade policies. A stronger EU Single Market also means a stronger EU, which in turn is expected to lead to more cooperation not only in terms of trade but also on other issues, e.g. shared decarbonization efforts.

The EU has already pledged to reduce its emissions by 80-95% by mid-century with respect to the 1990 level (European Commission, 2011), a goal that is likely to be upgraded to the net-zero emission goal (European Commission, 2008). If the rest of the world does not follow the EU efforts, the experts could envision two futures. In the first one, a number of "carbon tariffs" based on GHG intensities of the imported commodities could be implemented. In the second one, the EU could push for possible changes concerning trade agreements with other world regions. In this case, trade agreements could be used as a leverage for pushing climate policies in trade partners and transfer climate-friendly technologies towards emerging and developing countries.

Nevertheless, the participants also acknowledged that the impact of decarbonization efforts and climate policy on trade policy is highly uncertain. The food and energy sectors were used as examples in the discussion. For instance, a change in dietary patterns as part of

[4] In ENVISAGE v10, the aggregate land supply curve is allowed to have one of four shapes (isoelastic, logistic, hyperbola, horizontal), as needed by the modeller.

decarbonization efforts, intended as a change on the demand side, might lead to a surplus of food products with high carbon intensities that would be exported out of the EU. On the other hand, a reduction in the use of conventional sources for the production of energy may lead to an increase in import of energy generated by renewable resources; however, this may also lead to imbalances in the power grid because of peak supply and other intermittency-related issues.

3.3.3.2 Model-oriented dialogues

The group of experts in this discussion tackled the questions presented in section 3.3.3 from a CGE modelling perspective. In particular, the focus was on the selection of trade elasticities, differential productivity growth, the trade-to-income elasticity, and the short-run versus long-run aggregate supply functions for land and natural resources.

In principle, all the experts agreed on increasing the trade elasticities in the long run, but no agreement was reached on the magnitude for such an enlargement. In particular, their estimation depends heavily on the econometric approach. A number of suggestions to choose the appropriate elasticities were proposed:

- The usage of different short-run and long-run trade elasticities;
- For several scenarios a sensitivity analysis of the Armington elasticities could be conducted to illustrate their impact on the simulated transboundary effects;
- In the case of the European Single Market, the additional trade integration can be mimicked either by higher trade elasticities, or as lower bilateral trade costs faced by EU countries.

With respect to differentials in sectoral productivity growth, a number of dataset (FAOSTAT, EU-KLEMS, OECD-STAN) and Herrendorf et al. (2014) have been mentioned as possible sources. Estimations have been performed for CGE models (WTO, 2018a), showing that agriculture is the sector with the highest productivity growth at the world level. This is backed by the expected reduction in real price for food in the long-run. In some other modeling exercises(Chepeliev et al., 2018), exogenous energy efficiency improvements are calculated in each country proportionally to their GDP growth.

Regarding the long run relationship between GDP and trade volume, the experts suggested not to target a specific trade-to-income ratio to allow this to be endogenously determined in the CGE model by assumptions regarding changes in energy prices, productivities (especially in transportation) and trade costs such as tariffs. In particular, a reduction of trade costs by around 1% or 0.5% per year might be realistic and would help in 'targeting' a higher trade-income ratio.

With respect to the long-run projections of available natural resources, the experts suggested to target fossil fuel prices rather than designing a depletion function. Nevertheless, it was considered important to compare different price projections for coal, gas and oil (e.g. IEA, EIA and World Bank), and their effect on the baseline projection.

On the potential aggregate land supply expansion in the long-run, differences across EU Member States were noted by the experts. A number of countries can be considered "unconstrained", as the total supply of land can be increased, while other countries may be "constrained". In case a long-run land supply function has to be created, price elasticities calculated by Philippidis et al. (2017) may be used as a reference. This work makes a distinction between long-run and short-run supply elasticities. An alternative, similar to the one proposed for fossil fuel supply, could be controlling land prices by endogenizing productivities so as to implicitly target effective land supply. However, disagreement on this issue was observed among the experts.

4 Lessons and conclusions

This workshop brought together a group of active experts and stakeholders with relevant expertise in trade and climate modeling and/or with policy advising roles in leading research institutions and key international organizations and EU institutions. Most of the expert participants have extensive exposures and experiences in economic/trade modeling of climate changes. Their participation therefore greatly complements the technical expertise within the EUCalc project consortium in providing valuable insights and suggestions on the development of the transboundary module of EUCalc. This workshop was an important milestone in the research and design of the transboundary module, as the discussions at the workshop resulted in many important and insightful suggestions that will guide the development of the transboundary module. We plan to continue to engage the experts, those who attended the workshop as well as those who, although unable to attend the workshop, expressed their interest to be involved.

The workshop participants recognize the uniqueness of the EUCalc modeling approach and its potential contributions to the EU decarbonization debates. The major challenges associated with modeling the transboundary effects among the EU MS and between the EU and the ROW using "bottom-up" inputs from the rest of the EUCalc model, as presented at the workshop, are clearly understood by the participants. The discussions centered around three sets of questions distributed in the pre-reading material in advance have yielded many fruitful discussions. Some of these discussions point to useful recommendations and suggestions for the further modeling work in the transboundary effect module, whereas other discussions further reveal the complex nature of the modeling choices that the EUCalc team has to make in the modeling work.

Regarding the first set of the questions on representative scenarios to be formulated and simulated in the transboundary effect module, the experts agree with the team's general approach to only select and model relevant and representative EUCalc scenarios. On the three sets of scenarios that we proposed in the pre-reading material, the experts emphasized the need to pay attention to the scenarios that are likely to be used by users. One suggestion is to aggregate along the member state dimension and focus more on sectoral decarbonization differences. This effectively further reduces the number of scenarios to be modeled. Another suggestion is to model an even smaller set of scenarios and list them as pre-defined pathways in the EUCalc pathway explorer. In general, the experts cautioned against the ambition to model too many scenarios in a complex CGE economic model. The ideas of using the selected representative scenarios to "envelope" or representing the full set of EUCalc pathways are supported by the participants; however, the experts were quite cautious about the necessity and the feasibility to make "interpolations" to approximate the non-modeled scenarios.

On the second set of the questions regarding the exploitation of the results, the participants offered insightful suggestions and recommendations. They agreed with the need to further process the transboundary results into key indicators to facilitate the display of such results. Among the suggested indicators are the ones that can be derived from the modeling results, such as overall changes in trade balances and carbon leakages through trade by country and at EU level, and such indicators broken down by key sectors. Other suggested indicators were also mentioned, such as air pollutants and labor market related issues, which are out of the scope of the transboundary module but are dealt with in other EUCalc modules. Other suggestions are also mentioned on how to provide interactive menus on the pathway explorer to allow users to dig deeper into the results – a suggestion that will be investigated further.

The last set of the questions deals with both the macro level development of trade and globalization and the underlying modeling instruments of these macro trends, as reflected in the design of the baseline and the selected scenarios. Here, there is a broad support for the baseline compilation and implementation approach documented in D7.1. On the specific modeling issues that we brought for discussion at the workshop (e.g. long term trade policy trends, trade to GDP ratio, size of trade elasticities, sectoral productivity growth, oil prices, and land supply), it appears that modelers generally agree to a set of "best practices" (which are in fact being used by the EUCalc team) while recognizing the fact that the exact model implementations do differ across models and modeling teams. The specific suggestions gathered in this session pointed us to additional data, parameters and assumptions that will either be used or cited as further references in the modeling work.

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6 Annexes

6.1 Participants list

Participants – Stakeholders:

First Name	Last Name	Organization
Klaus	Mittenzwei	NIBIO (Norwegian Institute of Bioeconomy Research)
Eddy	Bekkers	WTO (World Trade Organization)
Jean	Fouré	CEPII (Centre d'étudesprospectives et d'informationsinternationales), Paris
Maksym	Chepeliev	GTAP (Center for Global Trade Analysis, Purdue University)
Alessandro	Antimiani	European Commission
Carsten	Wachholz	EIB (European Investment Bank)
Abderrahim	Assab	EBRD (European Bank for Reconstruction and Development)
Stephan	Zimmermann	World Bank / GFDRR
Marcel	Adenauer	OECD
David	Lopez	ECF (European Climate Foundation)

Remotely		
Hugo	Valin	IIASA

Participants – European Calculator:

First Name	Last Name	Organization
Wusheng	Yu	University of Copenhagen
Francesco	Clora	University of Copenhagen
Jeremy	Woods	Imperial College London
Tsan	Wang	TU Delft
Judit	Kockat	BPIE (Buildings Performance Institute Europe)
Ana	Rankovic	SEE Change Network

Facilitator:

First Name	Last Name	Organization
Adrian	Taylor	4sing

6.2 Workshop agenda

Thursday, November 22, 2018 from 10:30 AM to 5:30 PM CET European Climate Foundation (ECF) Building, 1040 Brussels	
Time	**Activity**
10:00 – 10.30	**Coffee/tea and registration**
10.30 – 10:45	**Opening & welcome -** *Workshop agenda, objectives, participants introduction* Prof. Wusheng Yu, University of Copenhagen Adrian Taylor, 4sing (facilitator)
10:45-11:10	**Presentation of the** EUCalc project- *Short overview presentation followed by clarifying questions and brief discussion* Prof. Jeremy Woods, Imperial College London Ana Rankovic, SEE Change Net
11:10 – 11:30	**Background to Transboundary module of the EUCalc**- *Short overview presentation on the methodology and assumptions* Prof. Wusheng Yu, University of Copenhagen
11:30 – 12:45	**Interactive dialogue #1**- *exploring the most important, relevant and representative user-defined pathways to be simulated in the EUCalc for generating the transboundary effects*
12:45 – 13:45	**Lunch**
13:45 – 15:00	**Interactive dialogue #2** - *discussing possible modalities for the transboundary effects to be presented in the EUCalc (e.g. as trade matrix itself or in terms of key indicators)*
15:00 – 15:30	**Coffee/tea**
15.30 – 17.15	**Interactive dialogue #3** - *reflecting on the long run relationship between GDP growth and trade expansion, the size of key parameters such as trade elasticities (e.g. Armington elasticities), the use of differential sectoral productivity growth pattern to generate expected structural changes, the treatment of land and other natural resource supply, and the representation of changing energy technologies in a trade-focused CGE model. Other issues to be discussed include recent setbacks in globalization and global cooperation, their implications on long run trade development and decarbonization efforts, as well as the EU's future position and role in global trade and global decarbonization efforts.*
17:15 - 17:30	**Wrap up and closing -** *Summary, key takeaways and next steps*

6.3 Dialogues' sheet

Topic #1 *Exploring the most important, relevant and representative user-defined pathways to be simulated in the EUCalc for generating the transboundary effects*	Questions: A. What are **the most important, relevant and representative user-defined EUCalc pathways/scenarios** to be simulated for generating the transboundary effects to be included in EUCalc? B. Are the three sets of scenarios mentioned below the important/relevant ones, and if so, **are we too ambitious in planning on simulating all these scenarios**? C. Are there **other important/relevant scenarios that are not included** in the three sets of scenarios mentioned below? There are three sets of scenarios anticipated: 1. Scenarios with identical ambition levels in all sectors and countries; 2. Scenarios with different ambitions across the sectors, with sectoral ambition levels being kept the same across EU MS; 3. Scenarios with deviations by individual countries from the EU-wide ambition, i.e. each EU MS is assumed to deviate its level settings (uniform across sectors) from the common level setting assumed for all other MS in the core scenario.

Topic #2 *Ways to present transboundary effects in the EUCalc (e.g. as the trade matrix itself or in terms of key indicators)*	Questions: i) ***What key transboundary effects*** (e.g. intra and extra-EU trade flows) should the model focus on? ii) At what ***sectoral aggregation level*** (i.e. no sector breakdown - the economy as a whole - or broadly defined sectors such as agriculture, manufacturing, services and the energy sectors, or more detailed sectors actually represented in the model) and for which ***key sectors*** should results be presented? iii) ***How should the transboundary effects be presented*** in EUCalc (e.g. as the trade matrix itself or in terms of key indicators such as self-sufficiency ratio, trade dependency/exposure index, revealed comparative advantage index, etc.)?

Topic #3a *Reflecting on the long run relationship between GDP growth and trade expansion, the size of key parameters such as **trade elasticities** (e.g. Armington elasticities), the use of **differential sectoral productivity growth** pattern to generate expected structural changes, the **treatment of land and other natural resource** supply, and the representation of changing energy technologies in a trade-focused CGE model.*	Questions: i) In the baseline projection, what guidance can you give on adopting appropriate ***trade elasticities*** given the expected major structural changes in the world economy? ii) What approach should be taken on modelling ***differential sectoral productivity growth***? iii) Assumptions regarding the ***trade-to-income elasticity*** are essential. However, this elasticity appears to have been falling in recent years relative to its long-run trend. So, should we assume a linear, or a changing link between GDP growth and trade expansion? How can we mimic this relationship in the baseline projection? iv) Regarding the treatment of long-run supply of ***land,*** **would it be reasonable to assume a simple land supply function? If so, what is the appropriate size of the land supply elasticity? To model the long run supply of natural resources, would it be sufficient to target a set of natural resource prices (e.g. crude oil and natural gas prices)**?
Topic #3b *Issues to be discussed include recent setbacks in globalization and global cooperation, their implications on long run **trade development and decarbonization efforts**, as well as the **EU's future position** and role in global trade and global decarbonization efforts.*	Questions: i) Regarding trade policy trends, are recent setbacks in globalization and global cooperation merely a transitory phenomenon or will they be the persistent norm, and how do these trends impact long-run ***trade development and decarbonization efforts***? ii) What impact will trade policy trends have on the ***EU's future position*** and role in global trade and global decarbonization efforts? iii) Are we expecting a **different relationship between GDP growth and trade expansion** in the next three decades, as compared to the experience in the last several decades when trade expansion has generally outpaced GDP growth?