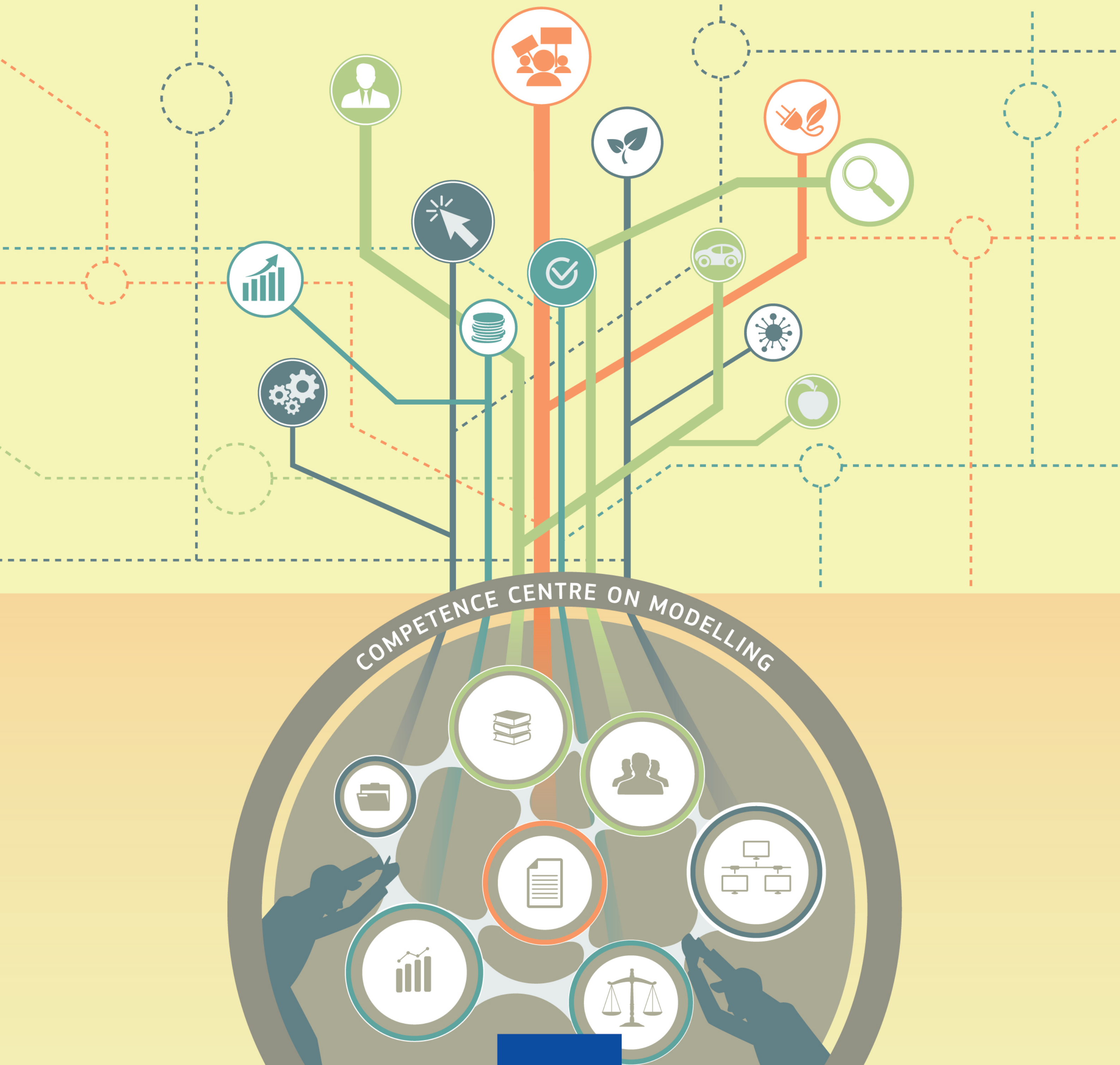
European Commission

EU Conference on modelling for policy support

26 - 27 November 2019 - Brussels

Abstracts



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26 November

10:00 – 11:00

Use of global models for policy recommendations

Mechthild Wörsdörfer, Director of Sustainability, Technology and Outlooks, International Energy Agency

The 'EU Conference on Modelling for Policy support: Experiences, challenges and the way ahead' in November 2019 in Brussels is the first time the EU Competence Centre on Modelling CC-MOD hosts a large-scale conference. I appreciate the aim of bringing together researchers and policy-makers involved in modelling activities. A broad and diverse range of conference participants are expected from European and international institutions and agencies, Member States, Universities, research institutes, and consultancies.

The conference will provide helpful in promoting exchange between modellers and policy-makers and thereby improve understanding between professional stakeholders. Participants of the conference convene to learn from each other's models and to act as sounding board to each other. Exchange on state-of-the-art approaches to modelling is prerequisite for the community to develop common principles, to compare its approaches, to resolve challenges and to ensure quality standards and progress in the advancement of model development. Not the least, it is important that modellers do test their model results in direct exchange with policy-makers in order to ensure applicability in the real-world context. Policy recommendations can be tested against sanity checks by practitioners and they can be tailored to increase their chances of realization in the political process.

The IEA has long-standing experience in the use of large-scale models for policies. Its flagship publication, the 'World Energy Outlook', builds on a comprehensive energy model covering global long-term developments of all fuels. The model ensures sophisticated techno-economic detail. It allows for concrete policy recommendations to IEA members and beyond based on bespoke modelling efforts. For example, modelling of the continent of Africa has been enhanced for a special regional focus featured in the freshly released World Energy Outlook 2019. The IEA thereby entered unchartered territory in developing detailed country-level models for the African continent, which is often neglected in terms of data and analysis. The IEA operates numerous detailed technical models which cover individual sectors in great granularity. These models form the basis for our publications in the area of energy technology policies. This year, IEA enhanced its modelling of hydrogen as well as geospatial analysis of offshore wind for the release of special reports. A finer temporal resolution with hourly analysis of storage and demand-side response was a key model improvement for the World Energy Outlook 2019. Altogether, its broad modelling activities put the IEA in a position as acknowledged and authoritative agency able to give advice on various energy policy areas covering all fuels and all technologies in the world. With its experience in using modelling for governmental advise, IEA is happy to share its model-specific expertise and knowledge with stakeholders. Various trainings and enhanced model and data transparency prove the agency's role as knowledge provider and its willingness to engage into dialogue with the modelling community. In fact, IEA proved its key role in promoting exchange within the modelling community when hosting the 2019 edition of the International Energy Workshop IEW in June 2019. The CC-MOD conference in Brussels provides for a good opportunity for mutual exchange and sharing of best practices and the IEA is honoured to take part in this endeavour.

Challenges lie ahead. The model community needs to follow numerous developments. First and foremost, **digitalisation and advances in IT landscape** set the scene. The pace of technological progress is both a curse and a blessing for policy modelling. On the one hand, advances in the IT landscape increase computational power and speed. New visualisation software allow for unprecedented ease in producing graphics and interactive tools. Usage and sharing of large-scale databases has become easier than ever before. On the other hand, the speed of change requires constant adaptation and flexibility. Tools which were state-of-the-art just years ago may be obsolete by now. Skills of today may be rendered useless in the near future, if no constant learning is ensured. The IEA, with its established long-standing modelling culture, copes with these constant challenges by continuous adaptation of its large-scale models over time. Enhancements to its models are made in an evolutionary manner, maintaining the good work of the past and ensuring high-quality output while equally benefitting from technological improvements. Where small models can be overhauled easily and re-built from scratch, large-scale modelling tools require a more careful approach for model development and resource planning.

Another major pillar for modelling developments is **transparency**. The European Commission was in the past often reproached for not sharing full details and assumptions of its modelling efforts on member state level. I noted this during my time at the European institutions. Similarly, IEA receives requests for sharing the entirety of underlying model data and assumptions. Striking the right balance between open-source and proprietary or confidential information is a question the whole policy modelling community faces. Stakeholders have interest in understanding models and they need to understand underlying data. The IEA recognises these interests and it is increasingly sharing its model results and data in a transparent and open format free of charge. The World Energy Outlook 2019 website offers unprecedented amounts of key assumptions without paywall. Nevertheless, the core of IEA's models and some of the modelling results remain either proprietary or they can be accessed at reasonable cost. Economic considerations lie behind these restrictions. Modelling is costly and it needs to be financed – most conference participants will understand.

Communication and visualisation techniques are a very decisive area to ensure success in the transformation of modelling results into real-world policies. Many stakeholders in the modelling community face a similar challenge as the IEA. In today's fast-paced media world, it is vital for communication to be timely, easy to understand and appealing to a broad audience. To get its messages heard by a wide audience, the IEA is constantly embracing innovative visualisation techniques. New graphing tools and interactive features provide for powerful ways of convincing policy makers and practitioners. They have become standard in conveying policy messages for striving institutions with high ambitions. The IEA is currently revamping its communicative tools in order to strengthen its outreach. The new IEA logo is at the start of a longer campaign to secure and expand the IEA's role as a leading authority in energy policy. A new website follows suite and will be released soon. New interactive features on the IEA website allow for better readability and make it easier to convey messages to the target audience with a broad range from laymen to practitioners and policy experts.

Model linkages are increasingly becoming key features in ensuring consistency between models and improving the understanding of the energy system. To which extent should models and modules be integrated? As a large agency, IEA operates different independent models. A big challenge is to ensure consistency across models for data, output and key results. Ideally, consistency is guaranteed through hard links between modules, but this is not always technically possible. Often, models are aligned manually through comparing results or use 'soft links' such as standardized exchange of input data. Most recently, IEA enhanced its modelling of hydrogen. As hydrogen is relevant for many sectors, technologies and regions, its modelling is an example of a cross-agency effort of model alignment. Interlinkages are omnipresent and they have to be reflected in modelling efforts when the ambition is to cover system dynamics. At IEA, we are proud to operate energy system models which span across all fuels, all technologies, all sectors and all countries. The ambition is to reflect the energy system in its entirety, without necessarily giving up on detail. There is no blueprint approach to get the optimum of models in terms of scope and detail. Surely, many conference participants will deal with this dilemma.

The IEA is happy to share its experience in modelling and policy advisory at the CC/MOD conference in Brussels. The numerous challenges we are facing at IEA are shared by many of conference participants. Therefore, it is good to engage into a fruitful exchange between stakeholder groups at the November 2019 conference in Brussels and I look forward to sharing my learnings of my time as Director at IEA with previous EU experience.

Parallel sessions 1

Model transparency and sensitivity analysis

Room 0.A
26 November
11:30 – 13:00

The challenge of achieving modelling transparency for policy makers

Rosen R. A., Tellus Instute

Many types of integrated assessment models (IAMs) are utilized to facilitate policy making world-wide, including in the EU. This is especially true for policy assessment research on environmental topics, including the mitigation of climate change. In cases that are all too common, these models are really just 'black boxes' for policy makers, and even for other research analysts in the same field of inquiry. There are at least four major aspects of the lack of transparency of most IAMs:

1. The equations – sometimes a few of the key equations are listed in fairly abstract form, but rarely is a complete list of all the substantive equations ever provided in model documentation. Furthermore, model documentation rarely describes how the equations are solved, even though the solution technique can sometimes matter significantly. The solution techniques are especially important to understand since most IAMs are highly non-linear, and yet need to be solved over a period of decades which can introduce cumulative errors in the solution by the end of the solution time period.

2. The coefficients within the equations are almost never explained or defined clearly, and the way in which they are derived from historical data (or theoretical assumptions) is never explained. Even their numerical values are usually not provided. Further, model documentation often does not even describe the time period over which historical data used to estimate the coefficients. Obviously, for policy makers to have any confidence that the IAM in question is up-to-date, they need to know the end-point of this time period. Finally, the likely accuracy of the historical data relied on is usually never discussed, nor is the issue of whether these historically-based coefficients should be changed in the future in model applications.

3. The values of other input assumptions/coefficients that are not statistically estimated based on historical data are only partially supplied in model documentation, even when these input assumptions are key to understanding the model results. Also, since many input assumptions are often projected for many years into the future, it is often not clear what methodologies have been utilized to make those projections.

4. The results of IAM runs are often overly aggregated in the published literature so that detailed aspects of the results that might help reviewers better understand the reasonableness and implications of the results are not available. Usually, there is little evidence as to whether even the model developers and users look at detailed model results to help them determine if the results are reasonable, counter intuitive, or just plain wrong, since there is almost never any detailed discussion of model results presented.

Most policy makers are probably aware of at least some of the problems with transparency listed above. But what can realistically be done to solve these problems so that policy makers can have more confidence in the modelling results on which they would like to rely? Model developers, of course, generally do not want to address the above list of problems because it would take many research hours to do so, and would subtract from their research budgets for doing the type of work they enjoy most, which is probably writing up their results for peer-reviewed journals.

This implies that policy makers and journal editors need to re-think the entire process of peer review in light of the four types of transparency issues listed above. For example, what good is claiming that a proposed journal article has been peer-reviewed if most aspects of the model itself cannot be peer-reviewed for the current submission, and have never been peer reviewed. Clearly, good science, as well as good economics, cannot be done on a 'trust me' basis. At some fairly recent point in the history of the development of an IAM the model itself must have received a thorough peer review, otherwise what is the value of just reviewing the write-up of various model results in a proposed journal article? Thus, the EU Competence Centre on Modelling must work with model developers, model users, scientific colleagues in each research field, peer reviewers, journal editors, and report editors to enhance the entire peer-review concept and practice for IAM-based research.

Obviously, however, this first requires that model documentation in the future must include all the four ingredients listed above. This implies that research budgets must be explicitly set aside for doing all of the additional work required to achieve this higher level of model documentation. Furthermore, all IAM-based research papers must be accompanied with clear tables of all key input assumptions used for each model run/ scenario relied on in that paper. Doing this will be a big help to the readers and peer reviewers of those articles for understanding the significance of each scenario or model result.

For example, it would be relatively easy when examining mitigation scenarios for climate change to understand why one model or scenario has much nuclear power for producing electricity in the future than another, if the former scenario assumes much lower nuclear capital costs than the latter. Yet, IPCC and other reports rarely provide policy makers with these kinds of key input assumptions for each scenario presented in their reports. If improved model/ scenario transparency were achieved, then a policy maker would know which scenario to focus on depending on their view of the likely values of the input assumptions. Without knowing the key input assumptions for each scenario considered for inclusion in a policy assessment report, policy makers are incapable of coming to any rational and scientifically based conclusions as to appropriate policies to recommend to governments.

The analysis in this paper is based on the author's extensive review of the limited documentation available for the kinds of integrated assessment models typically relied on in IPCC Working Group III and similar reports. The author has also been a peer-reviewer for various journals of proposed articles that rely on IAMs, and is a member of The Integrated Assessment Society

It started with a KISS: making complex modelling accessible, transparent and understandable

Caivano A., M'Barek R., Ferrari E., European Commission, Joint Research Centre

1) Modelling in the policy and research life cycles

Model-based analysis supports the European Commission in impact assessments and analysis of policy options. In the area of agriculture policy analysis and related areas, modelling constitutes a key component for evidence-based policy making.

The modelling work belongs to the 'formulation' phase of the policy cycle, where the impact assessments are located. For a transparent policy-making, this process has to follow highest standards to allow for tracing back all decision making.

Therefore, the modelling for policy support has to include the full step of the research life cycle, which does not stop with the publishing of a report. Instead, it has to ensure open access, dissemination within social media (e.g. making understand metrics through visualization) and preservation of the information in sustainable formats and reliable storage.

To this end, the Joint Research Centre (JRC) of the European Commission has developed DataM as a tool which provides interactive dashboards and raw datasets resulting from the scientific activities of JRC and partners, relating in particular to the economics aspects of agriculture and sustainable resources. Thus, it is a complement to scientific publications, aiming to improve the usability of traditional scientific reports largely based on big and complex data outcomes. DataM provides the readers with on-line tools that enable the self-analysis of data and allows full accessibility and storage.

2) The challenge of explaining model output

Support to policy with (economic) modelling tools has to ensure that the outcome is i) accessible, ii) transparent, iii) traceable, and iv) understandable. Without saying, it has to provide results and recommendations in a timely manner and with high scientific quality.

DataM[1] (Data portal of agro-economics research) was built by the JRC as a tool for responding to these challenges. It provides meta-information on the models, including links to documentation in order to allow a precise understanding of each model's specification. Graphical user-interfaces offer flexibility in supporting the appropriate use of models and their outputs by different user types (e.g. 'viewers', 'users' or 'developers').

3) DataM in details

The concept at the basis of DataM is to exploit the web plus the recent business intelligence technologies to improve the usability of our scientific literature. Scientific articles, especially in the case of economic studies relying on modelling exercise, are largely based on big and complex data outcomes.

Users take great advantage from the usage of on-line tools to self-analyze model outcomes from personal perspectives. This is a paradigm shift as compared to the traditional scientific articles that show only some charts and tables in accord to authors' choices.

This is also a significant improvement as compared to the simple provision of complex raw data outcomes, not accompanied by any tool and guidance to interact efficiently with them. The site is based on:

i) a data-warehouse where we manage datasets, often linked by the JRC open data catalogue, the EU open data portal and the European data portal. Normal users can only download data whereas modelers can also upload results by managing version, meta-data, reference data and harmonization logics.

ii) a business intelligence engine for interactive infographics and dashboards. The infographics include some narrative to resume the results of studies presented in interactive way with a top-down approach (from generic concepts to details). The dashboards are straightforward screens based on charts, maps, tables and filters interrelated among them.

DataM belongs to the acknowledged tools within the section 'EC knowledge, publication, tools and data platform' of the internet portal of the European Commission.

4) Example 1: Free trade agreements study

A good example is the 2016 study on 'Cumulative economic impact of future trade agreements on EU agriculture'. The study, announced by Commissioner Hogan at the Agriculture Council meeting and published (15 November 2016). Models used: MAGNET and AGLINK Interactive dashboards, data to be downloaded through a query portal or as a bulk.

The dashboards are actually short versions of the report with interactive visualisations.

In 2019 the negotiations on an EU-MERCOSUR free trade deal gained momentum and were closed at the Osaka G20 meeting 29 June 2019. Analysts and press did consult the report intensively.

5) Example 2: BioSAMs and SAMs

The tool is also supporting the storing and visualization of analytical (used for modelling purposes) databases such as Social Accounting Matrices (SAMs), which are typically employed to calibrate Computable General Equilibrium models. A SAM is a comprehensive and economy-wide database recording data on all transactions between economic agents in an economy over a certain period of time. SAMs are large databases which include national account

1 https://datam.jrc.ec.europa.eu

data plus a series of micro data used to disaggregate the economy at stake to the level of details needed for the analysis. DataM is currently storing a EU28 plus all Member States' Social Accounting Matrices with a detailed disaggregation of the bio-economy (Mainar Causapé et al., 2018). The tool allows researchers to download all the available SAMs which can be used in any single-country modelling approach or to visualize the key indicators included within the database in a friendly manner.

Based on these sets of SAMS, DataM produced an interactive tool to provide the number of jobs that would be generated by an exogenous shock in final demand for the selected commodities. This number accounts for direct, indirect and induced effects, calculated after (an infinite) feedback effects. The tool shows the variation in job creation in each of the sectors shocked and the aggregate variation (total jobs, jobs in the main productive sector of the commodity, jobs in the other sectors).

In addition, DataM is also storing and provide visualization tool for SAMs, developed within the JRC food security projects, for Sub-Saharan African countries. So far Kenya and Senegal SAMs are include while Ethiopia is about to be uploaded.

Knowing unknowns: adapting uncertainty and sensitivity analysis for impact assessment and policy-making

Becker W., Rosati R., Albrecht D., European Commission, Joint Research Centre

Uncertainty in modelling

With the increase of computing power and abundance of data, mathematical models have become increasingly prominent tools in policy-making. Models give the possibility to quantify the impacts of alternative policy options, the results of which can be used to support decision making. Models have also become increasingly complex, as they aim to model economic, physical and social systems with ever-higher resolution.

However, even the most advanced models are approximations to reality, which means that the results are inherently uncertain. That does not mean that models are not useful; properly done, a model represents our best understanding of how a system behaves. Nevertheless, depending on the context, our best predictions may still be very uncertain. This is particularly the case when forecasting long-term impacts or modelling complex and poorly-understood systems, as is often the case in policy-making.

In this context, it is essential that uncertainty is acknowledged, and quantified to the extent possible. To do otherwise risks important decisions being made on evidence that may not be very reliable, which ultimately can lead to poor policy-making.

The practice of quantifying the uncertainty in the results of a model is called uncertainty analysis. Uncertainty analysis involves identifying and quantifying the sources of uncertainty in a model, such as assumptions and input parameters, and propagating their effect to the model output.

Sensitivity analysis (SA) is a related and complementary discipline which apportions the uncertainty in the model results to each of the sources. Sensitivity analysis is often used to mean both uncertainty and sensitivity analysis, since in most cases an uncertainty analysis is a pre-requisite.

Sensitivity analysis in impact assessments

Recognising that these are important ingredients in model-based studies, European Commission (EC) guidelines on impact assessments (IAs) have recommended uncertainty and sensitivity analysis since at least 2009.

This work aims to investigate to what extent sensitivity analysis is practiced in EC impact assessments. Using a combination of text mining and reviewing nearly 500 IAs over the period 2011–2018, we find that the uptake of sensitivity analysis has been slow, although recent years show encouraging signs of improvement. Most impact assessments still do not include a sensitivity analysis, including many that are based on modelling or quantitative analysis. Moreover, sensitivity analyses are often performed in a manner that can greatly underestimate uncertainty, by varying one assumption at a time.

This problem is by no means unique to the EC. A recent review has shown that even in top-cited academic literature, the occurrence of a statistically-sound sensitivity analysis is relatively uncommon. What causes this gap between recommendation and practice?

Problem identification

In our opinion, a number of factors contribute to the problem. Among the main ones is a lack of time: policy officers are under considerable time pressure to complete the many tasks associated with an IA, and SA can be a time-consuming exercise. This may often be coupled with a lack of the high-level knowledge and statistical/software skills required to perform a sound SA. Even for those with a technical background, sensitivity analysis can still be a challenging subject in some circumstances.

The personal difficulties faced by policy officers are complemented by wider systemic issues. There seems to be a lack of best practice examples, and low incentives. This may point to a wider issue, which is that uncertainty in modelling is under-appreciated, and that there may be unrealistic expectations of what models can reliably predict. This puts pressure on modellers and analysts to produce projections and forecasts in cases where it is infeasible, and to understate or neglect uncertainties. On top of this, typical modelling in IAs aims to project the impacts of policies many years into the future, so there is little or no accountability for unreliable forecasts.

Solutions

How can we address these problems? At the personal level, training is an obvious avenue to improve skills, and reduce the time taken to perform SA. Not all staff involved in impact assessments can be expected to be skilled in sensitivity analysis, but 'advanced practitioners' could be trained who can act as advisors within each DG. A network of practitioners could be established via the Modelling Community of Practice, for example, centred on the JRC's dedicated research/support group on sensitivity analysis. Sensitivity analyses could also be recorded as part of the MIDAS model database to provide best practice examples and help future IAs.

At the systemic level, addressing all parts of the impact assessment chain could help a shift towards a more 'uncertainty-conscious' culture. Policy makers could be given crash courses in awareness and decision-making under uncertainty. Quality control procedures (such as the Regulatory Scrutiny Board) could tighten the requirements for sensitivity analysis. Models and data should also be made transparent, which encourages responsible modelling. Reviews could also be performed which retrospectively analyse how successful policy modelling was from previous impact assessments, to learn lessons for future modelling endeavours. This would also add an element of accountability into the modelling process.

Finally, experts in sensitivity analysis should recognise that modelling in impact assessment occupies a particular niche which requires special considerations. Guidelines and training for sensitivity analysis often tend to be either over-simplified or intimidatingly technical. Like most parts of impact assessment, sensitivity analysis can be applied proportionately to the complexity and importance of the policy. One route could be to introduce a bronze/silver/gold system, which gives guidelines to follow depending on the requirements of the impact assessment. For example, a low-impact (bronze) policy proposal that relies very little on modelling might only require best-case and worst-case scenarios, and a candid discussion of uncertainty. In the medium (silver) case, an impact assessment which uses a cost-benefit analysis and some basic projections should at least investigate a range of scenarios corresponding to varying key assumptions simultaneously, and include a discussion of wider untestable assumptions. A full (gold) sensitivity analysis would require a global Monte Carlo exploration of uncertainties, and an analysis of the reliability of the modelling: this ought to be appropriate when large physical/economic models are used for high-stakes policy evidence. The idea of giving different 'levels' of sensitivity analysis would aim to direct the effort to where it is needed and to not impose unrealistic expectations in every case.

What has global sensitivity analysis ever done for us? A systematic review to inform policymaking through earth system modelling

Pianosi F., Wagener T., Department of Civil Engineering and Cabot Institute, University of Bristol

Computer models have become essential tools in earth system sciences, improving our understanding of earth system functioning and informing policy-making at various spatial and temporal scales. A key challenge in the development of computer models is that, even when they represent a relatively low number of physical processes, they can quickly exhibit complicated behaviours because of the high level of interactions between their variables and components. As the level of interactions increases, modellers quickly lose the ability to anticipate and interpret model behaviour and hence to evaluate that a model achieves 'the right response for the right reason'. The issue is made more problematic in earth system modelling where incomplete knowledge of the system, and the scarcity and noisiness of data, makes it impossible to 'validate' models simply based on their fit to observations. Lack of transparency about the scope of validity, the limitations and the predictive uncertainty of earth system computer models, can lead users to overestimate the model's predictive ability or, on the opposite hand, induce them to rejecting the model completely.

In order to tackle the above problems, more structured, transparent and comprehensive approaches should be used to fully explore the impacts of input uncertainties on model predictions. Global Sensitivity Analysis (GSA) is a set of statistical techniques that provides such a structured approach (Saltelli et al., 2008). GSA has the potential to massively advance the value of computer models in earth system sciences, contributing to more robust development, evaluation and decision-making. However, the application of GSA in many areas of earth system sciences is still relatively limited. We recently published a literature review to demonstrate the value of GSA by showing examples of what its application has achieved so far for scientists, modellers and policy-makers (Wagener and Pianosi, 2019). We organised our review into 10 generic lessons learnt. In this presentation, we will focus on 3 lessons that are particularly relevant for model-based policy making, and draw examples from our own recent work to demonstrate the point.

1. Consistency of model behaviour with the underlying perceptual model of the system is as important as the ability to reproduce observations

The predominant approach to model evaluation still largely relies on the comparison of model predictions to observations. However, even if model predictions reasonably fit observations, this might be a relatively fragile result. Indeed, the value of the fit-to-data criterion may be undermined by the large (and typically poorly known) errors that affect environmental data; the scarcity of the data themselves, which often do not represent the entire range of system conditions; or the unrepresentativeness of historical data when dealing with changing boundary (e.g. climate) or system (e.g. land use) conditions. Here, GSA can be used to understand how the model represents system controls, and how such controls might change in the future, which is crucial and sometimes more important than the model's ability to reproduce historical observations (e.g. Sarrazin et al., 2019).

2. If model predictions are expected to support decision-making, then they have to be sensitive to decision-related input factors

Earth system models are often used as tools to support decision-making, by assessing and comparing the effects of different decisions (which can be related to one or more model's input factors) on an output of interest to the decision-makers. In this context, an implicit assumption is that the decisionrelated input factors exert an influence on the output that is at least comparable to that of other uncontrolled factors, such as the model parameters or forcing inputs. While this influence might be present in the real world, one cannot take for granted that it is also present in the model. Indeed, models built for supporting decision-making typically integrate a range of interacting and often nonlinear components, which means that their responses to variations across their many input factors are not immediately obvious. Here GSA can help quantifying the relative importance of all these factors and verify whether predictions are sensitive to decision-related ones, which is a necessary prerequisite for the model to adequately support decision-making (e.g. Butler et al., 2014).

3. Even in the presence of practically unbounded uncertainties, learning about the relationship between model controls and outputs can be relevant for decision-making

Another area where GSA has been successfully employed is the investigation of so called 'deep uncertainties', i.e. input factors whose ranges of variability and probability distributions are poorly known and hence practically unbounded. The propagation of these uncertainties through a model is technically feasible, however the resulting predictions are typically spread over such wide ranges that they are hardly usable to directly inform decision makers. Here, GSA can be used to analyse model simulations and identify thresholds in the input factors that, if exceeded, would cause the output to cross undesired output thresholds. Decision-makers can further complement these results with other sources of information to assess how likely those input thresholds are to be crossed in the future and hence determine whether actions may be required (e.g. Almeida et al., 2017).

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Modelling of uncertainty in defining safe operating spaces (SOS) in aquatic systems for support of policy development

Gal G., Ofir E., Israel Oceanographic and Limnological Research

Efficient policy for the successful management of aquatic ecosystems requires balancing between the need to sustain the ecosystem over time and the need to provide, often conflicting, ecosystem services. Varying environmental conditions, and often large degrees of uncertainty, may hamper the development, and implementation, of successful policies for the management of aquatic. One approach to the merging of the objective of sustaining the ecosystem along with the continuous provision of ecosystem services is the definition of safe operating spaces (SOS). A SOS in essence defines the range of management measures that can be applied to the ecosystem in question while maintaining the ecosystem state variables within pre-defined ranges thereby sustaining the ecosystem over time. The ranges defined by a SOS, therefore, provides the much-needed information for policy development.

There is, however, a large degree of uncertainty associated with future conditions of aquatic ecosystems and the environmental drivers acting upon them thereby hindering successful policy development and implementation. Furthermore, aquatic ecosystem responses to environmental drivers are often unpredictable leading to a large degree of uncertainty, in many aspects, over various ranges of temporal scales. Hence, the reaction of the ecosystem to changes in the drivers is often hard to predict. In addition to the uncertainty associated with future conditions, an additional type of uncertainty hampers attempts to model and manage ecosystems. Known as deep uncertainty, this type of uncertainty refers to conditions in which managers, practioners, and stake holders may not agree on the appropriate models to describe interactions among a system's variables, or the probability distributions to represent uncertainty about key parameters in the models (Lempert et al., 2003). Thus, modelling tools utilized to assist policy makers in defining, testing and applying policy to resource management must account for both types of uncertainty.

In this study, I present two case studies on a medium-size lake in which I apply various modelling tools to assist in defining policies based on SOS that allow, on the one hand, sustaining key state variables and, on the hand, the on-going provision of key ecosystem service. In addition, I account for the two types of uncertainty in defining the range of options for policy makers.

The first case study includes the application of the food-web suite of models, Ecopath with Ecosim (EwE) and Ecospace, in order to define a commercial fishery's safe operating space (SOS). In order to address the difficulties associated with management under uncertainty I include uncertainty and deep uncertainty in the modelling process. I define the SOS based on varying levels of fishing efforts, lake levels, and submerged vegetation all based on historical ranges. I do so by running multiple, long term scenarios, using EwE and Ecospace models developed for the lake. I then incorporate future uncertainty in the abundance of various food web components and evaluate the impact on our predictive capabilities and our ability to provide effective advice to the decision makers and lake managers.

The second case study includes the use of coupled hydrodynamical-biogeochemical models to the lake in order to define allowable nutrient loading into the lake while sustaining acceptable conditions in the lake. In this case study, a series of scenarios of varying lake level and nutrient loading into the lake are tested and results are examined using a water quality index which allows definition of acceptable conditions which are translated into a SOS. I account for the two types of uncertainty by introducing parameter uncertainty into the process and a wide range of variability into the forcing conditions. The results provide robust guidelines for policy makers required for defining acceptable level of nutrient loading and lake level changes.

Both cases highlight methodological approaches to assist policy makers in defining a policy that, under environmental uncertainty and deep uncertainty, will ensure continued provision of ecosystem services while sustaining the ecosystem over time. Though the case studies are applied to a medium-sized lake the approach is general and can be applied to ecosystems in general.

Parallel sessions 1

Scenarios, model linkages and data for policy 1

Room 0.B
26 November
11:30 – 13:00

Assessing the costs of EU truck CO_2 targets with DIONE and VECTO models

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Introduction

As a part of its endeavour to limit global warming under the Paris agreement, the EU's low-emission mobility strategy [1] has reconfirmed the aim to decarbonize transport. While Heavy Duty Vehicles (HDVs) are responsible for about a quarter of CO_2 emissions from road transport in the EU and for some 6% of total EU CO_2 emissions, their emissions were not regulated in the EU until this year. Therefore, the preparation of the proposal for the first-ever HDV CO_2 targets [2], presented by the European Commission in 2018 as a basis for the recent EU regulation, required substantial efforts of data collection and rigorous modelling to assess the impacts of alternative regulatory options. In close cooperation with DG CLIMA, the European Commission's Joint Research Center (JRC) has provided sound data for policy making and employed the DIONE and VECTO models to assess the societal and user costs under diverse regulation scenarios, as well as reconstructed a reference baseline for HDV fleet emissions, as contributions to the impact assessment [3].

Setting up robust HDV Emission Data with VECTO

Prior to 2018, the energy efficiency of new HDV in the EU was not assessed and monitored officially in the EU. Thus there was considerable uncertainty with regard to the actual situation regarding HDV emissions. As HDVs are highly customizable in order to fit to their users' needs, it is challenging to design a laboratory certification test like in the case of light duty vehicles. For this reason, a simulation approach was chosen for their emissions certification and monitoring. The European Commission has developed the Vehicle Energy Consumption Tool (VECTO), which vehicle manufacturers (OEM) have to use to certify the fuel consumption and CO_2 emissions of their vehicles.

In absence of respective data, a realistic HDV fleet-emissions reference baseline needed to be calculated for the regulation . The JRC was tasked to analyze large datasets provided by OEMs, which included VECTO simulation outputs for their 2016 model-year fleets and information on the sales numbers. To calculate a representative fleet-wide CO_2 emissions baseline distribution for the year 2016, in a stepwise approach the JRC:

1. Evaluated the data for inconsistencies,
2. Analysed the HDV fleet characteristics
3. Developed a methodology for normalizing the datasets in order to calculate a robust and representative 2016 CO_2 baseline and
4. Re-ran VECTO simulations for several thousand different vehicle configurations.

A key conclusion was that future reporting procedures must be standardised to prevent data inconsistencies. It was found that the initial calculations supplied were in some occasions overestimated, possibly leading to higher CO_2 emissions for the 2016 fleet. A baseline of lesser precision could compromise the robustness of any future targets to be included in the regulation. This was an essential observation for defining realistic CO_2 limits for the post-2020 period. More information can be found in [4]. The baseline established was used as a key input for the impact assessment accompanying the Commission's proposal for setting the respective CO_2 standards, and provided input to the economic modelling described below.

Cost Curve Development and Social/User Cost Calculation with the DIONE model

An important step of policy formulation is to evaluate the costs a policy causes and the corresponding impacts on affordability for users and OEM competitiveness. With its DIONE model, the JRC provides a modelling framework to assess the costs of vehicle CO_2 emission standards, first developed within the framework of the 2017 light duty vehicle impact assessment (see [5]). These modules have been adapted and extended to assess the costs of HDV emission standards. The interaction between the modules, as well as inputs needed and outputs produced, are sketched in Figure 1. The main HDV computational modules are described below. More information on the model is available in [6].

Firstly, the DIONE HDV cost curve model is used to develop curves which describe the technology costs of reducing CO_2 emissions of new HDV, compared to the 2016 baseline. It uses input data on available technologies, their emission reduction and costs, derived from the analysis described above and provided within the study [7]. An advanced optimization algorithm (Ants Colony Optimization) combines technologies into cost-optimal packages, and continuous cost curves are fitted. Some 80 final cost curves have been established for HDV. These cover the four VECTO classes addressed in the regulation, the fuels diesel and liquid natural gas, two drive profiles, the years 2025 and 2030, and typical, medium and high-cost estimates. An example of 2025 cost curves is given in Figure 2.

Figure 1: Flowchart of DIONE HDV modules

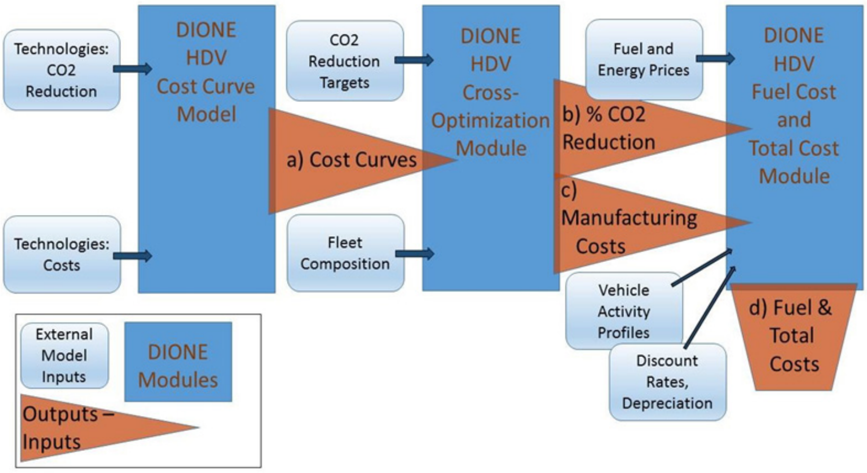
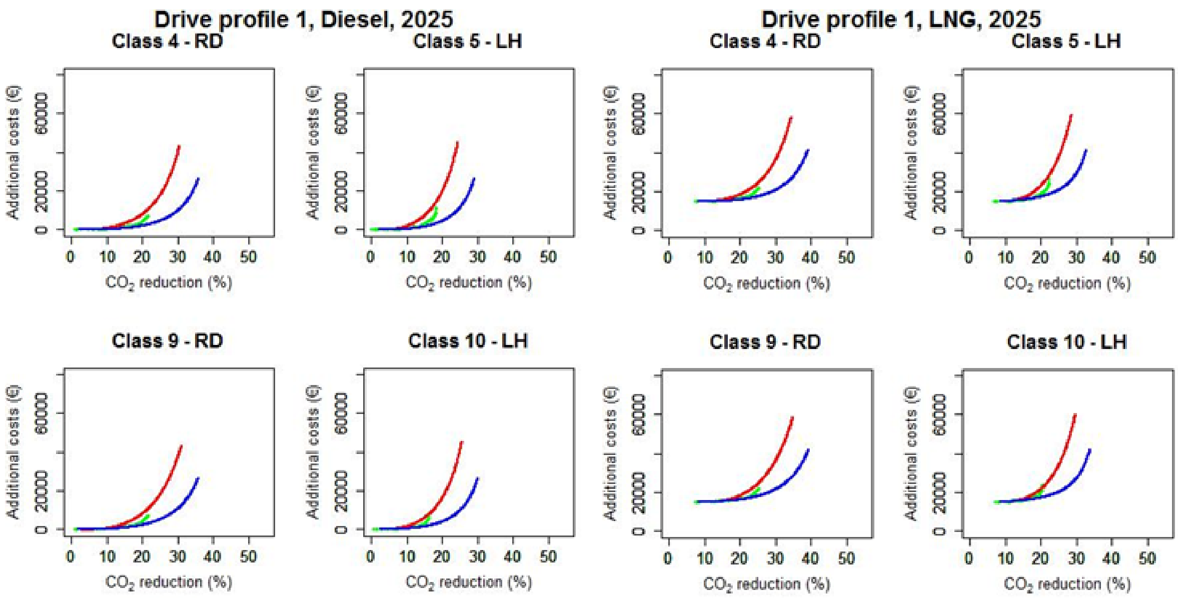


Figure 2: Fitted cost curves for HDV of the sub-groups 4 RD, 5 LH, 9 RD and 10 LH, for Diesel (left) and LNG powertrain (right) in 2025, for cost scenarios typical (blue), medium-cost (green), and high-cost (red)



Secondly, the DIONE HDV cross-optimization module runs an optimization to distribute emission reduction efforts over the vehicle fleet in a cost-optimal way, building on the cost curves. As inputs, it needs a given target for CO_2 reduction and the HDV fleet composition, the latter taken from an energy systems model scenario. Different options have been explored for HDV, including minimizing only technology costs, or total costs (including fuel savings) minimizing costs from different perspectives, e.g. that of a first user (vehicle life years 1–5), a second user (year 6–15), or from a societal perspective meeting relative (%) or absolute (gCO_2/km or gCO_2/tkm) emission reduction targets, set for the total fleet, or for vehicle classes separately.

Finally, the DIONE HDV total cost module calculates the fuel savings compared to a reference scenario, and the change of total costs of ownership caused by a CO_2 standard, from the user and societal perspective.

To inform policy-making, the above modules have been run for a wealth of settings, producing several hundred scenario outcomes. Extensive analysis has been carried out to understand the manufacturer and user cost impacts of different regulation options, and results for selected scenarios are included in the impact assessment for fuel efficiency standards for HDV [3].

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Energy systems modelling: toolbox development for policy decision support

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Introduction

A wide variety of models is being developed and used in the energy sector. Developers and users include academia, industry, policy makers, among others. Models can be found in very different shapes, serving a wide range of purposes. A model may refer to a conceptual, physical, or mathematical representation of a physical or economic system. In particular, a mathematical model tries to capture the behavior of a system by using mathematical equations or relationships. Based on observed/measured data, physical relationships, or indeed a combination of both, a set of equations can be defined that describe the relations between system variables, and as such the dynamics of the system..

Energy system models are developed and deployed to guide the transition of the energy system and to support energy policy-making. Specifically, long-term energy-system or power-system planning models are frequently used. These models typically span a single or multiple countries and cover multiple decades. In terms of model input, four categories of model input can be distinguished: the demand for energy services, fuel prices, technology descriptions (including their costs), and a policy framework. The output of these models is a description of the transition pathway: comprising information about the investments in different technologies, how these technologies are operated and the associated costs and emissions. Liberalized energy markets, climate change awareness and correspondingly increased levels of variable and limitedly predictable renewables, impose new challenges on the development and use of such models.

In this abstract/presentation, we will focus on two challenges/new developments in terms of modeling to support policy making, which we deem crucial in the future role of energy systems modeling:

- Providing transparent and flexible tools that allow model linkages and sharing of data
- Enlarging modeling perspective from centralized system optimization to a market-actor perspective

Model development
A flexible and open-source toolbox for modelling integrated energy systems

Due to the increasing complexity of the energy system, there is a growing need to integrate or link models covering different energy sectors or time frames. Currently, the vast majority of energy-system models have been developed with a specific purpose in mind (e.g., investment planning, unit commitment, gas flow simulation). Within the H2020 Spine project, the goal is to develop a flexible energy system model generator that is designed from the outset to perform these different functions and facilitate linking of models. Key features of Spine model are its generically formulated equations and the interface enabling a direct link between the data and the source code. In addition, the Spine toolbox contributes to facilitating model linkages and sharing of data by having an API to connect to databases of different formats, and tools allowing import and export of data in different formats. As such, the same data can be used to run a variety of models.

In addition, transparency is key for models used to support policy decision making. Using open-source models is a first step towards achieving transparency. In this regard, there is a trend to increasingly publish model source code in open access repositories. This practice not only contributes to transparency in the short-run, by making the model source code accessible to all who is interested, but also contributes to increasing transparency (and efficiency) in the long-run, by reducing the need of different institutes to develop their own, frequently similar, models. However, having access to the models' source code is not sufficient to achieve full transparency. A second aspect relates to transparency of data and data handling. Even when data is made openly available, possible barriers for transparency might arise as, depending on the license, certain data cannot be republished or shared. Moreover, there are frequently conversions happening from the raw open data and the data used as input for the model. The toolbox developed within the H2020 Spine project aims to create a workflow that enables connecting different data sources in various formats, and helps document the data trail to ensure full transparency and replicability of model results.

From a centralized system perspective to individual market actor behavior

To support policy making, long-term planning models are widely used to perform scenario analyses. Generating (and comparing) different scenarios can inform decision-makers about the environmental, economic, and social implications of certain decisions. Scenarios on various targets for renewables could, for instance, be run to assess the various implications.

Depending on the question that needs to be addressed, different types of scenario exercises can be performed. In this regard, one can distinguish between normative/prescriptive scenarios and descriptive scenarios. In normative or prescriptive scenarios, certain boundary conditions of a desired future state of the energy system are imposed upon the model. As such, normative scenarios provide information about the ideal transition of an energy system (i.e., where do we want to go?). One would typically deploy a centralized system perspective, single objective optimization model in this regard. Descriptive scenarios, on the other hand, do not impose a desired future state, but rather aim to describe a likely evolution of the energy system, i.e., given certain assumptions on fuel prices, technology cost evolutions, and policy interventions, how does the energy system evolve. Such scenarios can be used to evaluate whether certain policy measures could achieve the desired state, and if so, under which conditions. For instance, policy-makers could decide to implement a subsidy scheme for solar PV panels and wind turbines with the goal of reaching the target for the share of RES. A descriptive scenario would then allow assessing whether this measure is sufficient to achieve the desired GHG reduction targets and what the environmental, social and economic implications of this policy would be. Such descriptive scenarios are therefore crucial for translating the visions (where do we want to go?) which can be created using normative scenarios, to a specific policy portfolio (how will we get there?). Equilibrium and agent-based models are identified as targeted techniques for this descriptive perspective. These will be elaborated upon in the presentation based on the work currently conducted in the ELDEST[1] project..

Conclusion

The energy system is changing drastically: the levels of variable and limitedly predictable renewables are steadily increasing, and at the same time, massive infrastructure investments are required, in a liberalized market environment. In this context, models are needed to provide policy support on the development of proper policy mechanisms and appropriate market design. In this abstract, two key challenges are identified that need to be addressed to warrant future model use, so as to ensure solid input towards policy decision making: ensuring flexibility and transparency of models, and complementing the centralized system perspective with a market-actor oriented approach. In the presentation, we will elaborate further on these aspects.

Macroeconomic effects of EU energy efficiency regulations on household dishwashers, washing machines and washer dryers

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The JRC B5 unit (Circular Economy and Industrial Leadership) is producing impact assessments for the Commission's regulations on eco-design requirements for specific appliances. These impact assessments use both technical and economic information on the appliances production technologies and costs provided by stakeholders to evaluate the environmental and economic impact of

1 https://www.energyville.be/en/research/eldest-energy-policy-decision-support-toolbox

different available policy options using partial microeconomic and technical frameworks. The aim of the paper is to complement this analysis towards the use of the general equilibrium model FIDELIO, in order to provide additional information on the macro-economic impact of such regulations, taking into account not only the direct impact on the industries producing the appliances, but also all induced effects in the rest of the economy of the European countries. In particular, the paper focuses on the impact of two Commission's Regulations aimed at improving the energy efficiency of household dishwashers, washing machines and washer dryers.

FIDELIO is an econometric recursive dynamic multi-regional multi-sectoral general equilibrium model with some new-Keynesian features. The model offers a useful instrument to analyse policies influencing household consumption, being the household block modelled with relatively high details. In particular, households consume durable products (housing rents and vehicles) and non-durable products, such as appliances, electricity, heating, fuel for private transport, public transport, food, clothing, furniture and equipment, health, communication, recreation and accommodation, financial services, and other. For almost all consumption categories, the demand is characterized through econometric estimations.

To assess the impact of the regulations on household dishwashers, washing machines and washer dryers using FIDELIO, we introduce two different shocks for households. First, we assume a shock in the value of appliances consumed, assuming an exogenous shock in the price of appliances caused by the additional cost induced by the new regulation. Second, we assume a shock in the household consumption of electricity driven by the efficiency improvement of appliance induced by the regulation.

The main bulk of the data used in the model comes from the international supply and use tables of the World Input-Output database (WIOD) (2016 release). Additional information required is taken from CEDEFOP, Eurostat data, OECD data, the POLES model, UNECE data, World Bank data, and data from National Statistical Institutes of Belgium, China, Czech Republic, Hungary, India, Slovakia, Turkey, and the United Kingdom. Moreover, for this specific analysis, we use additional data provided by stakeholders, information from the 2010 Household Budget Survey micro-data produced by Eurostat, and previous analysis such as CLASP (2013)[2].

Considering the aggregate effect in the EU, the policies analysed would have a positive impact in terms of value added and employment on the industry producing washing and dryer appliances, and some related industries such as wholesale and retail trade sectors and the repairing industry. Besides, other industries would benefit due to the change in household spending driven by savings in electricity consumption (such as the food and beverage industry or the accommodation industry). On the other hand, there is a negative impact for the electricity industry and some related industries. For the economy as a whole, even if the impact on the value added is negative, the variation is relatively small compared to a baseline with no regulation (a decrease of 0.01% that is around 1.9 billion euro). The total impact on employment is instead positive (around 24 thousand jobs), being the industries that are better off more labour intensive than the industries negatively affected by the policies.

A food safety impact modelling system

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The emergence of a large-scale increase in food trade raises the risk of foodborne diseases and requires a status of ongoing

2 CLASP (ed.) (2013). Estimating potential additional energy savings from upcoming revisions to existing regulations under the ecodesign and energy labelling directives: a contribution to the evidence base (http://www.clasponline.org). http://www.clasp-online.org/en/Resources/Resources/PublicationLibrary/2013/CLASP-and-eceee-Point-To-Additional-Savings-from-Ecodesign-and-Energy-Labelling.aspx. last accessed on 08 Apr 2015.

awareness and readiness by Government authorities (e.g., national health authorities, food standard agencies) and industry (e.g., supply chain stakeholders). Having an early insight as to emerging food safety risks is essential to this state of preparedness. Furthermore, increasing global complexity of trade links over recent decades has led to increased opportunity for economically motivated food fraud and associated risks for brand owners.

Over the last four decades, many food-related scandals (both through unintentional incidents and fraud) have contributed to the global concern around food safety. The global integration of the food system increases supply chain complexity, inevitably increases the risks associated with food safety (Ellefson et al., 2012) and the need for compliance with international quality standards (Lemanzyk et al., 2015). The human cost related to foodborne outbreaks is extremely high: 600 million – almost 1 in 10 people in the world – fall ill after eating contaminated food and 420,000 die every year[3]. Nevertheless, the impact of food system failures is much higher than medical costs and lost productivity. The inability to meet food safety requirements may cause a vicious cycle generated by lower incomes and reduced access to food which, in turn, can lead to increased medical costs and decreased worker productivity (Devleesschauwer et al., 2018, p. 84).
The potential impact of food safety/fraud incidents on a business can be devastating; a single event can bring significant economic losses due to direct costs (e.g., disruption to operations while managing the recall, direct cost of recalling stock, analytical laboratory testing) and indirect ones such as the brand damage and loss of consumer confidence/change in consumption preferences (Kennedy et al., 2009; Hussain and Dawson, 2013). Moreover, it might cause the huge social costs comparable to the recent breakout of African swine fever in China. The Chinese government needed to take urgent action to detect and control the expansion of the infectious disease, to provide high R&D investments to create the effective vaccine, to deal with serious environmental problems of large numbers of infected pig carcasses resulting from the incident.

FERA Science leads the Work Package Confidence building and trade facilitation within the EU China Food Safety Partnership[4] with the aim to build confidence in EU-China trade by improved understanding of consumer practices and regulatory frameworks, the latter by developing and demonstrating mutual recognition of laboratory standards and results. Within this project, FERA is developing a modelling system to evaluate ex ante impacts of foodborne outbreaks/food frauds and food safety policies on agricultural production, income, markets, trade, and the environment, from global to regional scale economic impact.

1. The Food Safety Impact Modelling System (FSIMS) uses three modelling tools: An Early Warning System (EWS) to predict the probability of foodborne outbreaks/ food frauds;
2. A Simulation model to estimate the direct economic effect on various scenarios of outbreak/fraud detection periods based on detection standard operation procedures, laboratory validation, and quality control measures;
3. A Partial equilibrium model to estimate the ex-ante wider economic impact on the agricultural sector of different scenarios of the economic shock following the outbreak detection and the effect of food safety policies, namely the change in Sanitary and Phytosanitary (SPS) measures and agreements.

The EWS implemented by FERA allows for the estimation of the risk of foodborne outbreak/ food fraud. The EWS is a monitoring system concerned with examining a series of data and identifying changes. These changes reflect the mathematical properties of the dataset, such as sudden changes relative to recent history.

3 https://www.who.int/en/news-room/fact-sheets/detail/food-safety

4 http://www.euchinasafe.eu/

The simulation model calculates the direct financial impact of the foodborne incident based on the partial budgeting approach. Partial budgeting is a decision-making tool used to compare the costs and benefits. It only focuses on the changes in incomes and expenses that result from the decision process within the farm business. Thus, this approach is based on the principle that a small change in the supply chain can eliminate or reduce some costs, eliminate or reduce some returns, cause additional costs to be incurred, and cause additional returns to be received (Lascano Alcoser et al., 2011).

Turning now to the partial equilibrium model, the assessment of the economic impact of food-related incidents and food safety policies in the agri-food sector requires economic model-based projections of future agricultural activity levels. The aim is to use well-established models used to support policymakers at the European Commission and in China: The Common Agricultural Policy Regional Impact Model - CAPRI (Britz and Witzke, 2008) and the China's Agricultural Policy Simulation and Projection Model — CAPSiM (Yang et al., 2011; Xiaoyong Zhang, 2003).

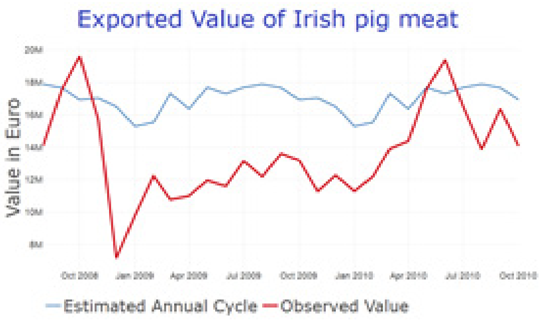
In order to set up the modeling system, we use case studies on past foodborne outbreaks, namely the Irish pig meat dioxin contamination incident (Kennedy et al, 2009; Tlustos, 2009) and the Chinese melamine outbreak in 2008 (Zhou and Wang, 2011; Xiu and Klein, 2010). The EWS can detect the high risk of an outbreak in both the case studies (Figure 1).

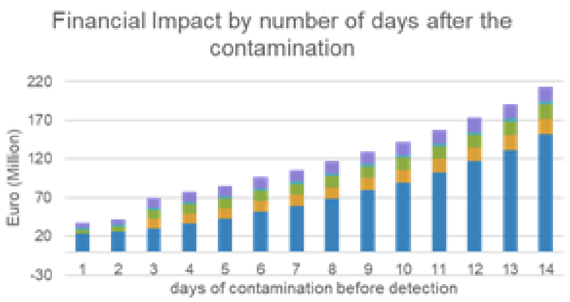
The EWS allows estimating the export loss due to the economic shock (€80.4 Million) following the decision to recall the pig meat-related products after the dioxin contamination in Ireland (Figure 2 left). Finally, the analysis of the economic tangible direct impact of the dioxin incident (i.e. costs along the supply chain due to controls, product recalls and destruction) reveals how the financial costs increase along the days of contamination detection (Figure 2 right).

There is a growing awareness of the challenges around the impact of food-related outbreaks and food safety policies (i.e., non-tariff barriers) to trade. The FSIMS will support decision makers (public authorities and businesses) by providing a standard tool for the assessment of the economic impact of food-related incidents and for food safety policy regulation. Moreover, the modeling system will have wider applications in terms of the ability to assist in the formulation of EU and Chinese agricultural and food safety policies, which have a potential to promote the growth of trade with restricting consequent negative impacts on the economy. Finally, the research outcome will augment the analytical capacity of the CAPRI and CAPSiM models and enhance their capability in terms of modelling of food safety in agriculture. The FSIMS will generate data for European and Chinese policymakers and will be able to mitigate the risks of ill-founded restrictions on agricultural growth.

Figure 1: Outbreak detection by the Early Warning System

Figure 2: Export Loss (left) and industry direct loss scenarios on the period of contamination detection (right)





Acknowledgements:

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The marine modelling framework of the EU Commission. A earth-system model for supporting policy decisions

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While the implementation of the Marine Strategy Framework Directive (MFSD) is progressing in the Member States (MS), the European Commission is building up its own analytical capacity in order to improve the understanding of the marine environment from an EU perspective.

The progress achieved during the last 30 years in marine modelling now allows a more realistic simulation of many aspects of the marine environment. The use of marine modelling can support the assessment process of the marine environment as foreseen in the MFSD by defining baselines, addressing data gaps and allowing for scenario simulations. To fully exploit this potential, the Commission is developing a modelling framework for the marine environment (MMF) including all aspects necessary to create a Regional Earth System Modelling tool (i.e., the atmosphere, the hydrology and the ocean living components (both biogeochemistry and high trophic levels)).

Holistic Ecosystem Assessment is required by the MSFD (and other EU pieces of legislation such as the CFP) in order to assess the achievement of Good Environmental Status (GES). Ecological modelling, combined with high-quality datasets, plays a key role within the implementation of the MSFD by supporting the assessment of the ecological state of marine ecosystems (for example in data-poor regions/periods) and allowing to evaluate different management strategies by creating alternative scenarios.

The models within the MMF have been already applied to a number of EU regional seas, from the Mediterranean Sea to the Black Sea, Baltic Sea and North Sea. These suit of models could provide information about different criteria addressing a number of descriptors of the MSFD such as 'biological diversity' (D1), 'commercially exploited species' (D3), 'marine food webs' (D4), 'eutrophication' (D5), 'sea-floor integrity' (D6), 'hydrographical alterations' (D7), 'contaminants' (D8) and 'marine litter' (D10).

However, and before the MMF could be used for policy support, it is necessary that the tools and their performance is scientifically evaluated and validated. With this aim, the JRC modelling team has produced a number of peer-reviewed articles in the last few years using the MMF as scientific analysis tool. The engagement of the wider scientific community in designing the MMF has been sought with the establishment of a network of experts in marine modelling (MEME group), which meet annually and provide inputs and feedbacks on the way JRC is implementing this work.

The level of confidence about the performance of the modelling tools to represent past and present environmental conditions in EU regional seas has allowed the generation of future scenarios in the context of climate change. Hence, management options could now be evaluated over the background impacts climate change would provoke in marine ecosystems.

In this presentation we will introduce the different components and the philosophy behind the MMF providing some specific examples of its application to policy questions in different EU marine basins.

Parallel sessions 1

Complex system modelling and multi-criteria decision making 1

Room 0.C
26 November
11:30 – 13:00

An accounting framework for the biophysical profiling of the European agricultural system

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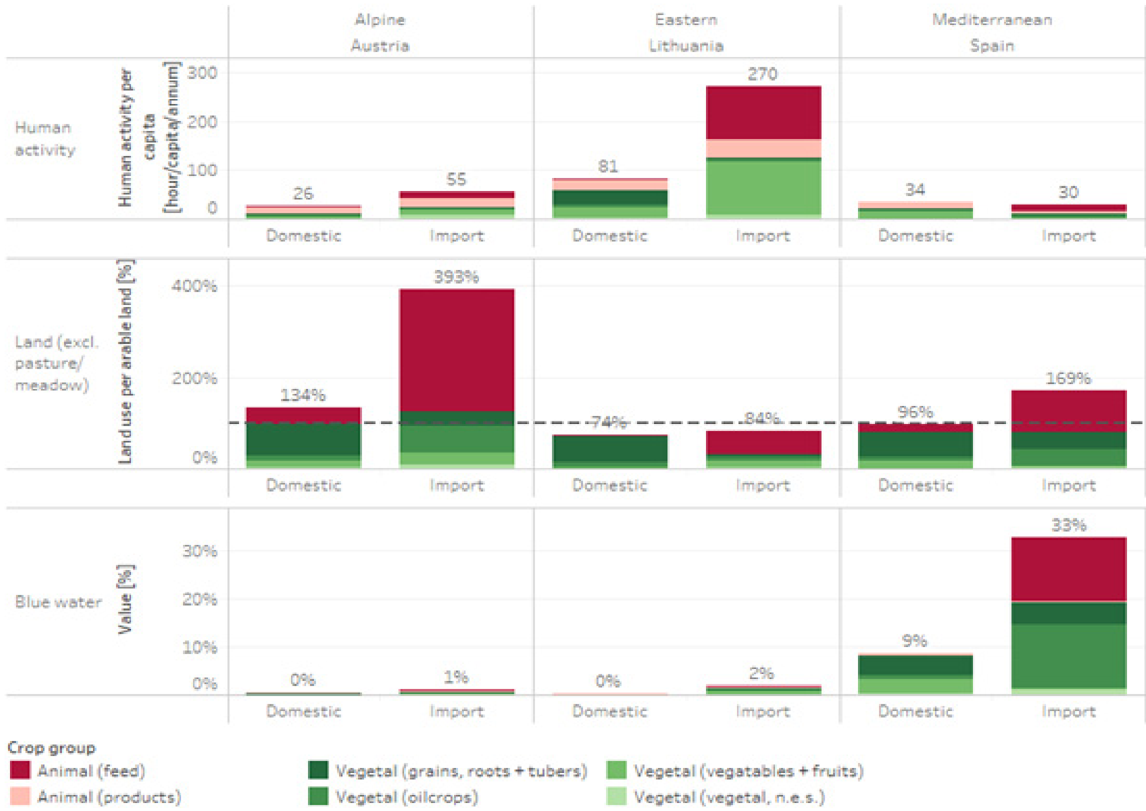
Environmental impact of human activity and related dramatic biodiversity loss are defining characteristics of the contemporary sustainability predicament. The concern to reduce environmental impact while preserving the integrity and the proper functionality of ecosystems has marked a point of consensus among citizens, civil organizations, and national and supra-national governmental organizations. However, in practice, equally legitimate but divergent interests of agents involved in socio-economic systems have made decision making oriented towards sustainability ever more complex.

In the agricultural sector, this situation is very evident due to the dilemma that exists—in terms of priorities—in terms of its importance and its consequences. The importance of agricultural activities is that they are responsible for providing nutritious and safe food to socio-economic systems, generating employment and economic benefits (for farmers, traders, and countries as wholes). Nevertheless, in causal terms, agricultural activities are among the primary drivers responsible for biodiversity loss and environmental impact. Furthermore, global megatrends of continuous population growth as well as changes in dietary patterns suggest that the impacts of agricultural activities will be accentuated in coming years. In this respect, the Common Agricultural Policy (CAP) has established nine objectives aimed at covering social, economic, and environmental aspects of sustainability from a perspective of sustainable development. For example, the CAP aims to preserve the socio-economic stability of farmers, protect the environment, improve food security,

Figure 1. Comparison between the biophysical resources (labor, land, blue water) used in local food production and the biophysical saving of these resources as a consequence of their externalization



and provide safe food to the population. The simultaneous achievement of all those objectives is a delicate balancing act which requires the taking of informed actions on complex events occurring across hierarchical levels—observable only across different scales—that are relevant to a diverse array of stakeholders e.g. consumers, traders, farmers, and institutions. A discussion ignoring the complex nature of these events and the context in which they take place can lead to misleading results. Therefore, it is imperative that decision makers concerned with agricultural option spaces adopt integrated, multi-criteria accounting methods capable of representing the complex relationships between: (i) resources that are under human control (technosphere) and those that are not (biosphere); as well as (ii) resources that are used in a direct way in domestic production and those that are used in an indirect way through imported commodities.

For example, taking coherent actions between the CAP and the Biodiversity Strategy would require more sophisticated analytical tools for studying the trade-offs between the productivity of agriculture and protection of nature when it comes to implementing green agricultural policies and establishing protected areas. In fact, in this discussion, there exists an elephant in the room which should be considered: the level of openness of the agricultural sector in the EU i.e. dependency on imports. This consideration is especially important in view of the massive increase in the requirement of food production expected in the future at the world level and the risk of geopolitical turmoil that requirement could generate.

This work presents a novel accounting framework based on the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) approach and tailored to the analysis of the water-food-land resource nexus. The versatility of this approach allows the quantitative contextualization of narratives focused on sustainable development. In order to demonstrate the usefulness of the approach, an analysis of the European agricultural system (EU-28 plus Norway) is carried out. This analysis allows for:

1. the quantitative operationalization of the formal relations between system components operating both in the technosphere and the biosphere
2. to characterize the pattern of internal consumption of food (that which can be affected by dietary changes)
3. to identify for whom and/or for what purpose system components are necessary
4. to quantify the level of commercial openness as a framework for the discussion of food security
5. to characterize the requirement of primary sources (land uses, water, fertilizers, pesticides, etc.) and primary sinks (emissions, waste, etc.) associated with the total consumption of a society
6. to differentiate the pressure exerted both on the local environment and the environments of other societies i.e. via externalization.

The combination of these results provides a system diagnosis and set of indicators capable of informing decision makers concerned with state assessments, including data referring to processes under human control such as population-scale nutrition, the technological requirements of food production, and the level of commercial openness of the agricultural system, as well as pressure assessments, including data referring to processes outside human control such as the local and externalized demand for a variety of ecological services. Additionally, the spatial contextualization of these pressures allows for an analysis of environmental impact.

The results show that the European agricultural norm is found to be one of substantial externalization of both social and ecological resource requirements on an order of magnitude at least as large as the internal requirements for production factors including labor (human activity), green and blue water use, and land use (Figure 1 shows examples of the results). Indeed, the externalization of agricultural production represents a major hurdle confronting Europe's sustainability goals and deserves more attention among policymakers.

Integrative planning for a sustainable, prosperous future

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Is there a way to quickly gain a helicopter view of the impact of certain policies across all social, economic and environmental sectors of society and discuss it with a diverse of stakeholders? Can we intelligently develop policies that can be both sustainable and prosperous? What economic, social and environmental consequences could arise if the planet's temperature were to rise 1.5 degrees by 2050?

Models based on Threshold 21 (T21) technology has been continuously developed over the past 30 years as a tool for policy development by the Millennium Institute, a not-for-profit organization [1]. Models have been applied in over 40 countries worldwide and have been used to develop plans for national development, green economy, sustainable agriculture, renewable energy transitions, industrial reform and Sustainable Development Goal planning in such varied contexts as Denmark, Mongolia, Peru, Senegal, South Africa and the United States [2], [3].

Additionally, they have been employed to study economic, social and environmental consequences of various climate change scenarios [4], [5]. Models comprise 30 sectorsbroadly categorized as environmental, social and economic and are built followingthe System Dynamics (SD) methodology, which excels at deconstructing and analyzing complex socio-economic environments and policy systems [6]. This method of simulation aids in garnering insight into complex relationships between constructs [7].

The thirty sectors in the base model, which together capturing dynamics in land use, water demand and supply, emissions and waste, soil nutrient, energy, consumption and generation, material consumption, biodiversity, population, fertility and mortality, health, education, poverty, income distribution, employment, infrastructure, finance and balance of payments, agriculture, industry and service production and government expenditure. These all modeled and interact with each other. Each sector has its own mechanisms and is designed to be comprehensible within itself. We provide detailed descriptions of the model through a model documentation available online [8]. Additional indicators and sectors can be modeled depending on the context, project and availability of data.

The calibration process of the model is essential to the building of confidence in its structure and results. Firstly, preliminary simulations are conducted to validate the model with respect to historical data. Further, we take the model structure and conduct simulations within it. Then, hypothetical single- or multi-policy scenarios can be introduced and its effect on indicators across all sectors can be analyzed.

Model structures are grounded in scientific research specific to each sector [8].

Additionally, system dynamics researchers also offers a great wealth of research and debate into how to model specific structures and its effects on socioeconomic systems [9]. Continuous refinement of the base model after each subsequent project, constant comparison with data, partial model and full model testing methods are used to ensure it has a good fit with the data and are in line with the research that the model is based off of.5,10. Each model is calibrated using data specific to each context the model is applied to. This is typically a country, however the models have been developed to sub-national and supra-national contexts.

With a fully calibrated model, many hypotheticals can be tested, with projections of many indicators shown across thirty sectors. Additionally, policy scenarios can be simulated with realistic, costed interventions and the effects they have on model dynamics and results can be seen instantaneously. Combinations of interventions can be simulated within the model, and often positive synergies can be found with interventions integrated together. As one of many examples, typically health and education infrastructure investment is more effective if roads are invested into at the same time, as clinics and schools would become more accessible. T21 encourages collaborative policy planning that is inclusive of what is happening across all sectors. An intuitive interface as well fully transparent model allows for planning across often siloed government ministries, private sectors interests and other stakeholders, which will help policy makers to form integrative solutions to pressing societal problems often at lower cost, while taking into account other needs. The model offers a space in which to easily assess the relative impact (both positive spillovers and negative consequences) of differing investment and policy scenarios for more inclusive policy-making.

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Decision support system for maritime spatial planning within blue growth and ecosystem-based management

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Introduction

The main challenge of PLASMAR Project is addressing the implementation of the Maritime Spatial Planning Directive 2014/89/EU (MSPD) within the present framework of emerging maritime activities linked to Blue Growth development and within the limits of ecosystem-based management. The main goal is to provide a pilot zoning, for the

Exclusive Economic Zone of the Macaronesian Region (Azores, Madeira and Canaries archipelagoes), including aquaculture, offshore wind energy, mineral extraction, fisheries, maritime tourism and transport, based on environmental sustainability. It is with this aim that PLASMAR Project has developed a Decision Support System (DSS) based on available scientific knowledge, collection of scientific data and developed research.

Data collection

The first step was data collection, which was developed gathering products delivered by European/global data initiatives: mainly Copernicus (Eye on Earth), European Marine Observation and Data Network (EMODnet), European Environment Information and Observation Network (EIONET), but also Oceanographic Data and Information Exchange (IODE), national/regional and local data infrastructures. To facilitate the collection of data and information, a Maritime Spatial Planning (MSP) data framework was developed within the project, comprising:

1. Marine Strategy Framework Directive 2008/56/EC (MSFD): Good Environmental Status 2017/848/EU (GES) parameters;

2. Marine Protected Areas information;

3. Coastal Land Use data;

4. Physical Oceanography data;

5. Current maritime activities and uses.

The principles of the INSPIRE Directive 2007/2/EC were applied to data collection, harmonization, and sharing.

Decision Support System

The developed DSS INDIMAR, is a web application which is fed with the collected data and available scientific knowledge — gathered by review of scientific and technical reports. The DSS delivers a multi-criteria analysis to define environmental suitability of the analyzed maritime sectors within the Exclusive Economic Zone of the Macaronesian Region. Suitability is based on the MSP data framework parameters (more than 80), assessed relation to each maritime sector, and significance given as a weight. To define the parameters' weights, an analytic hierarchical method was used, in conjunction to questionnaires filled by project partners, sectorial experts and finally stakeholders, during the set of meetings and workshops.

As a result, INDIMAR DSS, provides the identification of areas with environmental sensibility, areas of potential conflicts among maritime sectors, areas with significant lack of data, and, finally, pilot zoning areas for each maritime sector.

The final version of the DSS INDIMAR will be publicly available as an interactive web application.

Policy support within the DSS INDIMAR

Developed model and respected results will be used by competent authorities (Portugal & Spain) for finalizing Maritime Spatial Plans for Azores, Madeira and Canaries, needed for maritime sectors development and a requirement from the MSPD 2021. Final product Decision Support System INDIMAR results includes:

- A planning scenario based on the preservation of the marine environment, meeting suitability with respect to the MSFD Good Environmental Status parameters. This scenario identifies marine areas for the development of maritime sectors, where the expected impact on the environment will be minimized;
- Planning scenarios based on the coastal and oceanographic conditions potential for maritime sectors development (e.g. wind strength, depth… applied for offshore wind parks);
- A planning scenario based on the avoidance of conflicts among maritime sectors.
- A scenario that integrates all previous scenarios.

In June 2019, was approved follow up project - PLASMAR+ (2020–2023), where planned to carry on development of the DSS, including the social and economic components in the model.

Acknowledgements

This work was developed within the framework of PLASMAR Project ('Setting the basis for Sustainable Maritime Spatial Planning in Macaronesia'), which is supported by the European Union and co-financed through the European Regional Development Fund (ERDF) via the Operational Programme of Territorial Cooperation the INTERREG V-A Spain-Portugal MAC 2014–2020 (Madeira-Azores-Canarias).

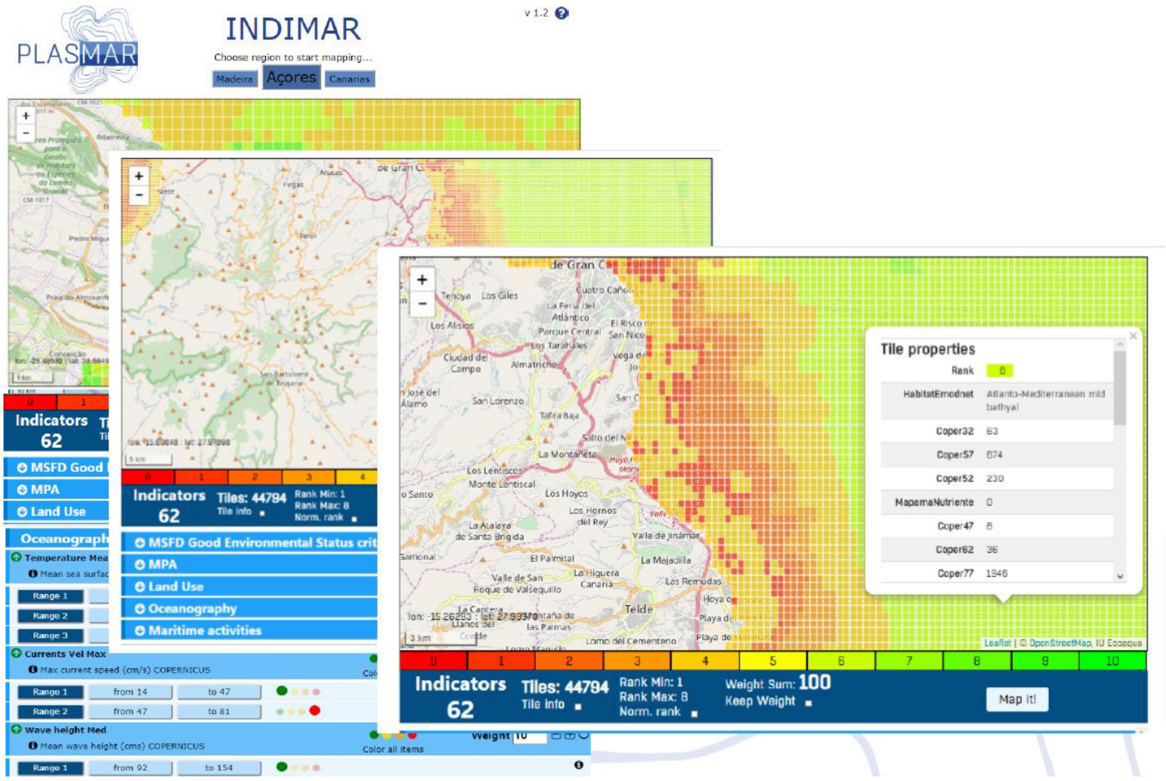

Figure 1: INDIMAR DSS snapshot, suitability test for the aquaculture facilities

Methodological reflections on the European Commission's 2013 use of CBA for air pollution policy

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Cost-Benefit Analysis (CBA) has been an important decision support tool for environmental and air pollution policy for decades in Europe and the European Union (EU). Today in many EU countries, some sort of socio-economic impact assessment (IA) of policy proposals is mandated by law, and commonly CBA is utilised. With the help from the advancement of applied environmental economics, CBAs have started to consider non-market external effects that a contemplated project or policy would have, thereby relaxing the assumption of 'no externalities' in the idealistic 'market under perfect competition'. There are now continuous method and application developments, as well as guidance efforts to increase transparency and streamlining CBA. Thanks to the inclusion of externalities and the streamlining of methods and data, one of the European environmental areas where CBA is used to check socio-economic soundness (that benefits will be higher than costs) of policy proposals is since some 20 years air pollution policy.

On the 18th of December 2013, the European Commission (EC) changed their approach to CBA. Instead of using CBA to corroborate net socio-economic benefits of a policy ambition level, CBA was used to model the 2025 air pollution emission levels where marginal costs of emission reduction would equal marginal benefits (i.e. maximize modelled welfare). This CBA model result then served as quantitative basis for the proposal of a 2030 policy ambition level, after adjusting to administrative and political considerations. CBA was thereby used to prescribe a policy proposal, and consequently used at a high degree of precision: the model results specified 2030 emission levels for 5 pollutants in 28 countries. This new use of CBA to prescribe emission targets for policies was justified via reference to technological infeasibility of reaching the EU long-term air quality objectives formulated in the 6th and 7th environmental action plans, and via adherence to economic rationality.

In parallel development with the new EC use, the academic critique against CBA for environmental policy has been growing. As examples, Ackerman et al. (2009) argues that CBA, or rather integrated assessment modelling (IAM) for prescription of climate policy ambition, is difficult to defend from an epistemic stand-point. And Pindyck (2013, 2017) basically dismisses IAM (CBA) as useless. Further, Gowdy (2007) stress the need to adjust conventional CBA with respect to lessons learned from the research field of experimental economics. The common themes in the critique related to uncertainty, discounting, equity, incommensurability, and problems in valuation methods are all perhaps most attenuated in climate policy but also applicable to air pollution policy.

This presentation scrutinizes the new EC approach to air pollution CBA (AP-CBA) by reviewing recent research developments of relevance for CBA and by reviewing the policy process in which the CBA was done. This review is appropriate since there are omissions in earlier overviews and reviews. Pindyck (2013) in his critical climate CBA review proclaimed CBA as fit for purpose for air pollution problems but did for natural reasons fail to recognise the policy closeness and prescriptive nature of the recent EC AP-CBA proposed after Pindycks' publication. Further, even though Gowdy (2007) and Brennan (2014) presents interesting new research and perspectives on how to adapt CBA to knowledge developed by experimental economists, there are yet more perspectives necessary to complete the picture. Other overviews and reviews have been re-iterating the same critique that has been heard for decades now (Frank 2000), without adding much new substance whilst aiming their message at new audiences (Hwang 2016, Pindyck 2017). Still other texts seem to accept the textbook CBA-concept fully and mainly focus on ensuring that the reader of CBA results is informed on key sensitivities in CBAs (Dudley et al. 2017). But none of the reviews and critique properly addresses the practice of basing CBA on prospective scenarios, nor do they appear to consider policy environments in which the CBA is made. The purpose with this review is to discuss and assess the potential reasons for why policy makers are using even more exact CBA-results for air pollution policy despite a growing body of methodological critique against CBA. The guiding questions are: Despite a large and growing body of arguments against the use of CBA, how can it be that CBA currently is used in a prescriptive and high-precision version in an air pollution policy context? Is the latest EC approach to CBA fit for purpose? How high impact would any change in approach reasonably have? And what are the alternatives to the current approach?

Overall the review suggests that the academic support for scepticism towards CBA results has increased during the last years and have gotten more dimensions: system analytical, experimental, and psychological. Further, there are several indications that the reality of air pollution policy is changing. More focus is now on individuals than in the past: if so, decision making by ordinary citizens will become more important for future air quality and a modelled optimal emission level assuming economic rationality will be rendered less reliable. Based on these results it could have been argued that the 2013 EC use of AP-CBA to serve as basis for a policy proposal was an example of over-confident use of model results. However, the air pollution policy process provides input that also needs to be considered, where the importance of a rational approach to policy support and the political process must be kept top-of-mind. After all there are indications that the new AP-CBA approach encouraged higher policy ambitions than earlier approaches.

It can be settled that it is an impossibility to require truthful predictions from models used for prospective studies of unmeasurable parameters, and democratic policy processes are likely to result in political ambition levels different from modelled ambition levels. The policy effect of any model improvement is uncertain, but model developments are nevertheless desirable. Future AP-CBAs should compare alternative solutions to reach policy ambitions as well as compare different types of ambitions. It is also important that the models used for policy support analysis complements the economic rationality presented in AP-CBA with other rationales.

Parallel sessions 2

Model quality and transparency 1

Room 0.A
26 November
14:00 – 15:30

Challenges and opportunities of integrated policy modelling

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Policy challenges are increasingly complex and go beyond traditional policy or model areas. This requires more than ever before combining models for in integrated assessment framework (e.g. water'energy-agriculture; demography-migration-climate-economy, etc.). The benefits of an integrated use of models to support policy making are more and more acknowledged both by policy makers and modellers.

However, an integrated use of models for policy is associated also with challenges and pitfalls which are not encountered (encountered less) when using a single model to address a specific question in one policy area. This paper attempts to raise awareness of key challenges related to an integrated use of models for policy support. Secondly, we attempt to identify approaches allowing some of integrating modelling pitfalls turn into opportunities, if addressed in a timely and appropriate manner.

Policy questions. Many policy questions can be answered by single models. In the same time, increasingly, today's global societal challenges require a joint use of models from different disciplinary areas (social sciences, environmental sciences, etc.). For example, modelling policy questions related to Sustainable Development Goals (SDG) requires an integrated modelling approach. The first set of challenges that we would like to point out relates to the formulation of policy questions as well as potentially conflicting interests of policy stakeholders related to the different models developed for different policy areas.

Models that are being linked often have originally been built for different policy questions originally. As result, the integrated system of models might have stakeholders with conflicting policy perspectives and expectations. Thus, when policy questions are complex and more than one stakeholder is involved, modellers may be confronted with different interests/stakes. Reaching one policy target may move the society further away from another policy target. An integrated modelling may reveal trade-offs between targets of different policies and an inconvenient truth about policy impacts. For example, an integrated modelling framework may reveal trade-offs between policy targets of environmental and climate policies on the one hand and energy and foreign trade policies on the other hand. The scientific integrity requires that modellers remain neutral, with independency from policy makers being assured[1]. Anticipating potentially conflicting interests of policy stakeholders behind the different models and conferring them transparently may help to mitigate conflicts between different stakeholders at later stages.

The presence of multiple stakeholders requires a careful formulation of policy questions — preferable this is done jointly by modellers and policy makers. It is generally a good practice but in the case of an integrated modelling it may be a particularly rewarding strategy to formulate policy questions jointly by policy makers and modellers by accounting for possibilities to analyse policy questions.

Multidisciplinary approach. Global societal challenges, e.g., energy, water, food security, global health and urbanisation, involve the interaction between humans and their environment. A (mono)disciplinary approach, be it a psychological, economical or technical one, is too limited to capture any one of these challenges. To understand policy impacts in presence of interactions between humans and environment requires knowledge, ideas and research methodology from different disciplines (e.g., ecology or chemistry in the natural sciences, psychology or economy in the social sciences). Hence, collaboration between natural and social sciences is needed.

1 For example, in several Member States the scientific neutrality of scientists is anchored in the national legislation governing scientific institutions.

Conceptual challenges. Models for policy support are built on certain theories, each of them contains assumptions, particularly models in social sciences disciplines. When integrating models from different scientific disciplines, likely, their theoretical frameworks will differ. Among these differences, those with contradicting theoretical insights should be paid a particular attention. The same applies to ensuring consistency in exogenous assumptions. A further conceptual challenge is related to interfaces/endogenous variables for linking different models. In a fully integrating modelling system, the same endogenous variables should not be computed by different sub-models, as in most cases their results will differ. Instead, an iterative feedback loop should be developed for enable to run different models iteratively and converge towards a stable equilibrium.

Empirical challenges. Different models use different sources of data and depending on the policy question also different baseline assumptions. When integrating different models, there is a fair chance that already the input data are inconsistent across different sub-models; the more different are the scientific disciplines for which the models have been developed, the larger will be these differences. To avoid and/or reduce inconsistencies among model data and baselines, exogenous assumptions and baseline scenarios should be aligned for those exogenous variables and parameters that are present in several sub-models of the system.

Even when models in different disciplines may use the same type of data, their spatial and temporal resolutions and other dimensions may differ significantly. For example, whereas an energy model in economics may suffice with an aggregated country-level energy supply data with yearly time steps, an energy model in an engineering discipline may work with data at time steps below hours at the grid level.

Consistent aggregation/disaggregation methods are necessary to address differences across models related to spatial and temporal resolutions and other dimensions.

Precision and complexity versus robustness and tractability. Integrated models have a tendency to become more and more complex, more and more detailed and thus more and more difficult to understand and validate. An integrated modelling entails a trade-off: trying to take the complexity of the world into account on the one hand and increased uncertainty and difficulty to understand model outcomes on the other hand. In order to approach the trade-off of precision and complexity versus robustness and tractability, a good common understanding of what is important across different disciplines and a positive attitude toward compromises are required. In order to avoid that integrated models become 'monsters', key insights from each scientific discipline (an educated compromise), as well as trust and respect between scientists from different disciplines are required. One way to find the appropriate balance for example between a very detailed natural science component and a very aggregated social science component could be to undertake a global sensitivity analysis of the integrated modelling system.

Transparency and quality assurance. Quality assurance / transparency is not an easy task because in integrated modelling systems data often come from a large variety of sources, errors percolate through the linkages, implying that ensuring a robustness of results can be a particularly challenging issue (more challenging than of single model results). Indeed, the more complex is the modelling system, the more difficult is to ensure robustness. One way of validation of integrated modelling systems is matching model results with past observations attempting to replicate historical data. Further, local experts from outside modelling teams can also contribute with their local knowledge to building a credibility of large integrated modelling systems.

Maintenance, updating and documentation. Large integrated modelling systems are challenging to maintain, update and document. For these tasks, dedicated data scientists in the integrated modelling team are required that are dedicated to the system maintenance, updating and documentation. Further, the continuity of staff in integrated modelling teams is even more important than for single models, as such systems tend to be more complex than single models. This is also important for building trust and credibility with the model users and other stakeholders.

Meta-modelling. A model is an abstraction of phenomena in the real world; a meta-model is yet another abstraction, highlighting key properties of the underlying models. In times of increasing policy complexities and interdependencies, developing/using meta models to provide integrated modelling solutions serves a feasible alternative to complex large integrated modelling systems. Rather than hard or soft coupling, a series of models or meta modelling might be an alternative. In several policy areas, such as the bio-economy, meta-modelling is well advanced in the European Commission already. For example, within the bio-economy domain several sectorial models have been interlinked and integrated in a coherent modelling framework

Modelling for EU policy support: impact assessments

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Hordijk L., Special Adivsor, European Commission, Joint Research Centre

The objective of this work is to systematically analyse how models are used in support to the policy formulation phase of the EU policy cycle. We focus on European Commission (EC) Impact Assessments (IAs).

The main framework of the EU regulatory policy, the Better Regulation Agenda (BR) (European Commission 2015), sets a clear commitment to a transparent and sound use of evidence for all EU policy making activities. The Better Regulation Guidelines (European Commission 2017), which complement the Agenda to provide concrete guidance throughout the policy cycle, recommend to quantify costs and benefits to the extent possible to support the policy formulation phase. In doing so, the EC makes extensive use of models. A better understanding of these models and how they are used can then contribute to a sound use of evidence in support to EU policies.

The Commission's Competence Centre on Modelling (CC-MOD) promotes a responsible, coherent and transparent use of modelling at the EC. As part of its activities, this analysis systematically investigates how models are used in support to the policy formulation phase, by looking at EC IAs which are publicly available. A total of 1063 IAs carried out in the years 2003 to 2018 have been investigated to examine the frequency and characteristics of model use, by using text mining techniques complemented by manual post processing. The research is facilitated by and feeds back into MIDAS, the Commission-wide modelling inventory and knowledge management system developed and managed by CC-MOD (Ostlaender et al. 2019), which directly contributes to enhanced transparency and traceability of models used to support policies.

Our results show that models are used in 16% of the total IAs (173 out of 1063 IAs), with a positive trend over time, starting with only two IAs using models in 2004, to around 25–30% from 2015 onwards.

We identified 123 different models contributing to IAs. More than half (53%, or 65) of these models were used only once, which leads to considerations related to the efficiency of model use and reuse in the EC, as well as on the scope for improved coordination of models related products and services. On the other hand, some models do dominate: the top 10 models contributed to 10 or more IAs, and were used in 66% (or 114) of the total number of IAs using models.

Included among the top 10 models are also those models used for the development of the series of EU Reference Scenarios, led by DG ENER, DG MOVE and DG CLIMA. Indeed, the consistent use of the same series of baselines in the areas of energy, transport and climate goes in the direction of increased consistency across policy areas and fields of analysis, though there is still room for strengthening the coherence in baselines across the whole EC. At the same time, given the dominance of these models to support the policy formulation phase, it is essential that they undergo careful quality scrutiny and that maximum transparency and traceability of results is ensured.

Policy areas with the highest numbers of IAs using models are environment (including climate), internal market, transport and energy. However, this could also reflect other factors, such as the frequency at which IAs are carried out in the various policy areas. In addition, it should be remembered that models can also be used in other policy relevant studies, or for internal notes and analyses which remain unpublished.

Finally, results show that 94% (116) of the total number of models that were used in IAs were used for ex ante assessment of policy options. This is to be expected, since indeed the assessment of policy options is an extremely relevant task for quantitative analysis in IAs. As mentioned, most of the top 10 models were also used for baselines.

In this respect, transparency is crucial to understand how models work and to validate their behaviour, to encourage their sound and widespread use in support to policy making contributing at the same time to a more effective and efficient use of resources for model development and use within the EC.

The mandatory requirement introduced by the BR Agenda in 2017 for an annex on 'Analytical models used in the preparation of the impact assessment' contributed to better model descriptions and an increased transparency of the methodology used. There is, at the same time, still room for improvement in better documenting models as the individual model descriptions in IAs are still quite variable in quality. The information and reports generated by MIDAS on models and model use can be used in this respect.

At the same time, we also identified some major challenges related to referencing in IAs, such as lack of harmonized and adequate references or outdated hyperlinks, which made the quantitative evidence untraceable in several IAs. Since 2017, the BR foresee that, when IA analysis relies on modelling or the use of analytical methods, the model should be documented in the corporate modelling inventory MIDAS (European Commission 2017). This represents a major step forward in terms of transparency. At the same time, it is also clear that further action is needed to use and promote best practices to ensure transparency and accessibility over time of the evidence base in support to IAs. In addition to the BR guidelines, the JRC, as the science and knowledge in house service of the Commission, can provide additional assistance and support to the Policy DGs.

To conclude, our analysis directly contributes to the implementation of the BR Agenda, by promoting transparency, coherence, traceability and accountability in the use of evidence for EU policy making.

From modelling guidelines to model portfolio management

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Guillaume J.H.A., Australian National University
Lahtinen T., Aalto University
Vervoort, R. W., University of Sydney

Numerical simulation models have moved from exploratory academic tools to become mainstream tools in decision making. Models are used in a variety of functions such as interpretation of monitoring data, design of monitoring networks, impact assessment, and scenario-based planning. Today, model-based assessment is prescribed by several environmental regulations and policies at multiple scales, such as the Water Framework Directive in the EU, or the Clean Water Act in Ontario, Canada. This abstract takes a high-level management perspective on these regulatory processes and offers the concept of model portfolio management in order to govern more effectively.

Multiple guidelines exist that clearly lay out: steps involved in a modelling project (e.g. Jakeman's Ten iterative steps in development and evaluation of environmental models);

criteria for how to choose appropriate model code or modelling methods (e.g. Vanrolleghem's Modelling aspects of Water Framework Directive Implementation); or detailed guidance on how to document a model application. There is, however, a lack of guidance that would help environmental managers effectively integrate simulation and decision models into the knowledge infrastructure of an organization, especially if compared with the abundance of guidance for developing and managing geospatial or relational databases. As a consequence, staff at most agencies that we encountered are managing modelling projects ad-hoc, selecting and applying modelling guidelines and tools based on personal preferences, without an explicit strategy of how to re-integrate the knowledge and tools obtained in a modelling project into a larger knowledge strategy. From an agency perspective, synergistic strategies for executing modelling projects could improve cost-effectiveness, impact, create more lasting benefits, while reducing dependence on individual staff.

Model management, or management of numerical models (MNM), is an overarching term that encompasses governance, operational support, and administration of modelling: the managerial procedures by which technical modelling projects are governed, 2) the technologies that make up an organization's infrastructure for data and modelling knowledge and IT support, and 3) the human resource aspects of how knowledge is accessed throughout the model's lifecycle (Arnold, Guillaume, Lahtinen, Vervoort, submitted). Reviewing lessons from research and practice highlights that management of numerical modelling projects could be greatly improved by moving from ad-hoc and opportunistic decision making toward intentional, 'explicit' governance of modelling projects with defined institutional goals and a long-term strategy for knowledge and software management. Senior managers perceive modelling projects as complex and requiring a multitude of difficult and highly specialized fields of knowledge, many of which are beyond their own expertise and comfort zone. Major barriers identified in our research are lack of awareness and/or priority by higher-level management, lack of examples to follow, lack of model management guidelines, over-ambition of modelling practitioners especially with respect to software tools, and an overall hesitation of senior management to address this issue.

Looking for analogous situations in the field of public management, 'project management' offers guidance for effectively dealing with single projects, and 'project portfolio management' guides high-level managers to orchestrate the efficient acquisition and execution of multiple projects. In a similar way, we define model project management as the process of effectively rolling out one modelling effort, and a model manager as someone who manages these efforts. Model portfolio management is an organization's governance approach that assures synergies and resource efficiency when implementing multiple modelling projects, assuring that efforts contribute to the building of knowledge infrastructure in ways that align with an agency's goals, and the operational and administrative support that an agency offers to its model managers.

We provide a systemization of the emerging discipline of model management around the functions that model applications fulfill for agencies, the tasks that the agency have to fulfill, and the leverage points that the managers of modelling projects have (Figure 1).

As one example, the Guide for Actively Managing Watershed-Scale Numerical Models by the Oak Ridges Moraine Coalition (Holysh, Marchildon, Arnold, Gerber, 2017) summarizes lessons and points out low-hanging fruit after reviewing consultant-agency relationships after Ontario designated drinking water protection areas and commissioned hundreds of diverse model applications. Recommendations range from simple rules for file naming and file directory structures, standard formats for data and metadata, over templates for consulting contracts with suggested formulations around intellectual property rights, to standard disclaimers.

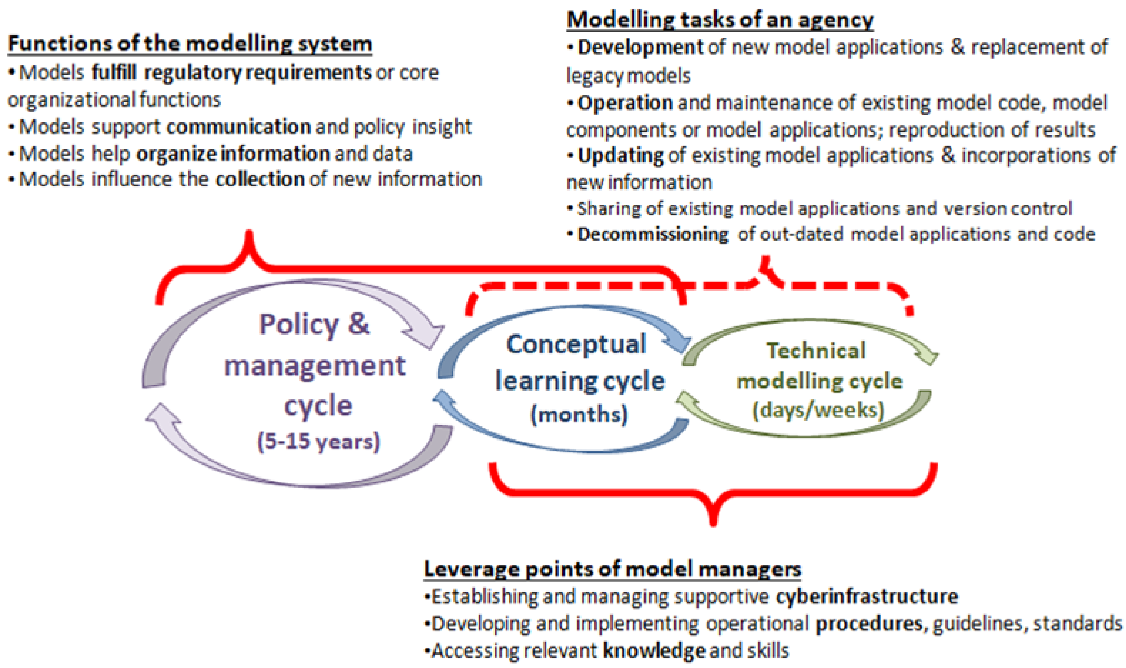
The guide also details potential for the role of a Model Custodian as a shared resource across multiple agencies. The custodian offers a custodianship plan that supplies a variety of model management tasks to an agency. This person also supports agencies in designing modelling studies, by formulating goals, requests for proposals and subsequent contracts; the custodian reviews proposals and later project deliverables but also offers a platform for archiving and sharing model applications or parts of these.

The principles of model portfolio management can be taken much further, as demonstrated by engineering consultancies, Earth System modelling centres, or operational watershed agencies. Synergies are derived from cyberinfrastructure workflow systems that are integrated with data and documentation standards, operational procedures and guidelines, tutorials and other education methods, and communication strategies.

Benefits include automation of complicated, repetitive, technical tasks, reduced duration and cost of modelling cycles, and reduced reliance on tacit knowledge by making hidden knowledge transparent. These organizations drastically reduced the cost of setting up a new model application, and made it easier to work in teams or transfer model applications from one staff person to another. Yet, many rural organizations point out a need for model portfolio management approaches with low overhead cost that are appropriate for staff without in-depth modelling experience.

The presentation will lay out principles for model and model portfolio management that were identified through our work. It also summarizes leverage points for how model portfolio management can be improved within public agencies, with the goal of promoting the transparent and cost-effective use of models as management and decision tools.

Figure 1. Management of numerical models within three embedded modelling cycles. Technical modelling tasks are interdependent with conceptual learning and policy & management activities



Post-hoc evaluation of model outcomes tailored to policy support

Thulke H. H., Lange M., Helmholtz Centre for Environmental Research GmbH — UFZ

Expert-knowledge based system models are flexible tools prepared to support strategy identification and policy decisions. Kitching et al. (2006) note the key question for any policy oriented model is whether decisions made with it are more correct than those made without it. Nevertheless, literature is scarce of scientific evaluations of modelling initiatives tailored to support policy decisions. This presentation addresses the issue using insights from three practical examples and targets understanding the chance and limits when answering the key question for policy oriented models.

In the EU a prominent area of policy models addresses health risks to plant and animals due to established (i.e. endemic) or invasive (i.e. foreign) pathogens. The real-world link between science and policy in the area has several grounds being food safety, wellbeing of organisms and nature conservation perspectives. The multiple dimensions of the objectives and the variety of potential pathogens hazardous to plants and animals justifies the great spectrum of modelling activities in support of policy decisions. Therefore the field of health risks management created individualised model tools of substantial complexity, ad-hoc hypotheses and often uncertainty regarding the system-level functioning/interplay of detailed process knowledge. Recent methods of mathematical computing allow mimicking both the detailed process knowledge driving logical conclusions in decision making together with the alternative mitigation action or even contradicting interpretations of observational evidence. The usually short time horizon between risk assessment, decision taken and real outcome makes the subject area a good arena for lessons learned.

We synthesise a list of model applications for decision support from past years addressing independent policy questions and different ecological and/or pathogen ensembles. We follow the pathway from model predictions to decision and post-hoc final outcome. The steps are illustrated with the interpretation of the decision needs translated into necessary modelling amendments and the quantitative model predictions. We use several historical assessments regarding wild boar (Sus scrofa). These problems cover natural expansion into naïve habitat regions as ground for species management in Denmark (Alban et al. 2005; Moltke-Jordt et al. 2016), the incursion of Foot-and-mouth disease in Bulgarian wildlife and the need for EU emergency action (EFSA 2012; Dhollander et al 2016), and the large-scale management following invasion of the African swine fever virus into European Union (Lange et al. 2014; EFSA 2017; Lange et al. 2018). Further the related managerial implication and implementation is discussed before the model outcome is challenged with the real world response to management decision.

The lessons learnt target three aspects of Kitchings' key question: the purposeful application of expert system modelling in crisis context when usually shortage of time argues against; the improved decision recommendation using these models i.e. why the potential decision implied was more correct; the cumulating trust in the model basis for decision support via outcomes derived for particular policy questions i.e. post-hoc adequacy testing. We present the quantitative predictions spatio-temporally explicit and compare it with the real world notifications for the example problems.

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The MIDAS touch — Maintaining an overview of model use by the EC through the EC Modelling Inventory and Knowledge Management System MIDAS

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Hardy M., Ghirimoldi G., UniSystems

The European Commission's (EC) Competence Centre on Modelling (CC-MOD) promotes a responsible, coherent and transparent use of modelling to underpin the evidence base for EU policies.

Maintaining an overview of ongoing modelling activities, by documenting the models and model combinations in use across the EC, is an elementary first step for a more transparent and coherent use of models in the policy cycle. It is, however, also a major challenge: for example, in the EC more than 150 models are currently being used. The list of domains ranges from greenhouse gas emissions, energy consumption and economy, to agriculture and structural integrity assessment, to name but a few. In addition, the majority of these models are run in combination with other models. Thus, they form complex networks of interaction, together with the related inputs, outputs and assumptions. Capturing this knowledge, and communicating it in an understandable manner to both scientists and policy makers, will not only foster transparency of model use, but enable collaborative and interdisciplinary research that serves cross-policy issues.

In order to address these challenges, and to grasp the underlying opportunity, CC-MOD develops and manages MIDAS, the Modelling Inventory and Knowledge Management System of the European Commission[2]. MIDAS

2 Ostlaender, N. et al. (2019) *Modelling Inventory and Knowledge Management System of the European Commission (MIDAS)*, EUR 29729 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02852-9 (online), doi:10.2760/900056 (online), JRC116242.

contains a description of models in use by the EC, which directly or indirectly support the policy cycle, independently of whether they are developed or run by the EC or by third parties. MIDAS is situated on the EC Network and accessible to EC staff, offering a platform where data, models, scientific publications and policy actions can be easily correlated, and where these connections can be browsed and better understood.

MIDAS was first launched in 2013 as an inventory of models run by the Joint Research Centre of the EC to directly or indirectly support EU policies[3]. After two successful first years of use, in 2015 the High Level Reflection Group of Information Management, whose investigations fed into the COMMUNICATION TO THE COMMISSION on Data, Information and Knowledge Management at the European Commission (C(2016)6626), recommended to extend the modelling inventory to the entire EC and to develop it into a corporate tool. In the following years, under the lead of a dedicated Inter-service group of the EC, the scope and audience of MIDAS was thus extended to include models used by any EC services to support the policy cycle. This now also included models run by external organisations, where the EC used the results e.g. in the context of an impact assessment.

When formulating the vision and scope for an EC wide modelling inventory we were aware that this was not just about designing a technical solution. Instead, great institutional, cultural and resource challenges lay ahead of us: scientists and policy makers had to invest time and resources to share their knowledge in an understandable manner and across different domains, with us and with their peers, and be ready to maintain the information updated as long as the models are in use.

The institutional challenges have been tackled through a solid governance structure, involving all EC services using modelling results to support the policy process. To work on the cultural challenge of sharing a common understanding of cross-domain issues, the continuous involvement of the community of modellers and policy makers is fostered through a dedicated and EC wide Community of Practice on Modelling.

To maximise the relevance for the users, MIDAS puts all models into their scientific and policy context, by combining the knowledge that various modellers and model users in the EC have about a model in a single place, where it can be browsed and visualised. Using data visualisation techniques helps to communicate the resulting complex network to a non-technical audience, revealing the bigger picture and allowing users to identify patterns about model use they might not have been aware of. In recent years we added tools that allow users to generate their own graphs and reports, answering user-specific questions like 'Which models run by the EC can be used for Climate Mitigation?' or 'Which Impact Assessments used the EU Reference Scenario 2016?'.

MIDAS was officially launched as an EC tool in October 2017[4]. Since 2017 MIDAS is also integrated in the workflow for EC impact assessments, as the revision of the Better Regulation Toolbox[5] requests that any model used in an impact assessment should be described in MIDAS. In the course of step-wise extension of the MIDAS audience, in 2019 parts of the system have been opened to the European Parliament (EP)[6].

The information and reports generated by MIDAS on models and model use can be used in practice in documents and reports, such as the compulsory annex introduced by the Better Regulation Agenda[7] for impact assessments on 'Analytical models used in the preparation of the impact assessment'.

3 Ostlaender, N., Bailly-Salins, T, Hardy, M., Perego, A., Friis-Christensen, A. dalla Costa, S., (2015) 'Describing models in context – A step towards enhanced transparency of scientific processes underpinning policy making', *International Journal of Spatial Data Infrastructures Research*, Vol.10, 27–54.

4 https://ec.europa.eu/jrc/en/event/conference/laucnh-cc-mod last access: 28th June 2019

5 European Commission (2017) *Better Regulation Toolbox*, accessible at: https://ec.europa.eu/info/better-regulation-toolbox_en, last access: 28th June 2019

6 MIDAS has been officially opened to the European Parliament during the Science Meets Parliaments event 2019. The opening was done under the umbrella of the Interinstitutional agreement of 13 April 2016 on Better Law-Making (Official Journal of the European Union L 123, 12.5.2016, p. 1–14)

7 European Commission, accessible at: https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en , last access: 28th June 2019

This could effectively contribute to the recommendation to enhance transparency on data, assumptions, methodology and results and to keep impact assessments understandable and useful for decision-makers, as suggested in the academic debate on Better Regulation[8].

This makes MIDAS an important corporate and interinstitutional tool to use, reuse and document models in a proper way, directly contributing to the dissemination and use of sound methodology underpinning the EC's Better Regulation policy.

8 Listorti, G. et al. (2019) *The debate on the EU Better Regulation Agenda: a literature review*, EUR 29691 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-00840-8, doi:10.2760/46617, JRC116035

Parallel sessions 2

Integrated assessment modelling

Room 0.B
26 November
14:00 – 15:30

Lessons from the use of the GAINS model to inform clean air policies in Europe

Amann M., International Institute for Applied Systems Analysis (IIASA)

Since 1995, the Greenhouse gas — Air pollution Interactions and Synergies (GAINS) model developed at the International Institute for Applied Systems Analysis (IIASA) has been used to inform Commission proposals and subsequent negotiations with the European Institution on EU clean air policies.

The long residence time in the atmosphere of the most relevant air pollutants like fine particulate matter and ground-level ozone implies that even within cities only a rather small share of pollutants concentrations originates from local sources. Effective reductions of pollution levels require coordinated emission cuts in a large region, often in other countries. Furthermore, fine particulate matter and ground-level ozone are caused by multiple precursor emissions, including primary $PM_{2.5}$, SO_2, NO_x, NH_3 and VOC. These are caused by a wide range of economic sectors, and the potentials for and costs of further cuts in these emissions vary greatly among the source sectors.

The GAINS model provides a knowledge base to support informed decision making about effective emission reduction strategies that achieve health and environmental improvements at least cost and maximize co-benefits on other policy areas, including greenhouse gas emissions.

GAINS brings together information on the future evolution of emission generating activities, the current state of applied emission control measures and resulting emissions for all sources, the potentials for and associated costs of further emission reductions, the chemical transformation and transport of pollutants in the atmosphere, and the impacts of ambient pollution on human health, agricultural crops and natural vegetation. Furthermore, the GAINS model quantifies for each Member State the co-benefits of more than 400 specific emission control options on the full range of air pollutants. GAINS can determine least-cost portfolios of these measures that achieve prescribed targets on health, vegetation and ambient air quality in the most cost-effective way and assess the resulting distributions of costs and benefits for different Member States and economic sectors.

Inter alia, the GAINS model has been used for the negotiations on the 2001 and 2013 National Emission Ceilings Directives. A series of studies conducted with the GAINS model for the European Commission explored the cost-effectiveness, benefits and the distributional impacts of alternative sets of national emission ceilings for $PM_{2.5}$, SO_2, NO_x, NH_3 and VOC for each Member State. These informed the proposals that were presented by the European Commission to the European Institutions. During the subsequent negotiations, IIASA conducted further studies for the European Parliament and the European Council on the implications of alternative policy proposals.

Based on the more than 20 year experience with GAINS , the following lessons can be drawn for model application to support policy processes:

- As policy decisions involve choices that will not necessarily please all stakeholders, scientific credibility (through a dedicated and transparent peer review) emerges as an absolute prerequisite for the acceptance of model outcomes among stakeholders with diverse interests.
- The same holds for the credibility and acceptance of input data among stakeholders. IIASA held multiple series of bilateral face-to-face consultations with more than 2000 experts from all Member States. Such efforts are unusual in the academic world and are usually not rewarded by academic systems.
- Open access to model and data over the Internet emerged as an important prerequisite for the acceptance of model results, and the international IIASA

supported its role as an impartial broker of scientific knowledge.

- While originally the focus of the analyses was on the identification of cost-effective policy interventions, during the negotiations attention shifted towards the distributional aspects across Member States, economic sectors and even within different groups of actors within key sectors).
- While originally the model was developed to facilitate a common multi-pollutant/multi-effect/multi-country/multi-sector framing of clean air policy, the course of negotiations added co-benefits on multiple policy other policy areas and the multi-level governance aspects (cities/countries/EU level) as additional dimensions.
- In this context, the interactions, synergies and trade-offs with climate policies emerged as an important issue, and GAINS is now used both by DG-ENV and DG-CLIMA for their different policy proposals.

Science for an evolved Common Agricultural Policy — the Scenar 2030 experience

M'Barek R., Ferrari E., Genovese G., European Commission, Joint Research Centre

1) JRC's support to CAP policy making with iMAP

The integrated Modelling Platform for Agro-economic Commodity and Policy Analysis (iMAP) started in 2005 with the idea of building up a platform to host agro-economic modelling tools financed by the European Commission, in particular European Union (EU) Research Framework Programmes. Financed mainly by the Joint Research Centre (JRC) and the Directorate General for Agriculture and Rural Development (DG-AGRI), it has developed into a policy support-oriented platform that disposes of a number of partial equilibrium (PE) and computable general equilibrium (CGE) models, among those AGLINK-COSIMO, AGMEMOD, CAPRI, IFM-CAP and MAGNET (for more details see summary reports 2012 [1] and 2015 [2]).

To serve the policy decision-making process, iMAP has to provide results and recommendations in a timely manner and satisfy high standards of scientific quality and transparency. Close links with the current policy agenda have to be maintained. Furthermore, harmonised, public databases should be used whenever possible. In ex ante analysis, baselines, harmonised between models and accepted by clients, provide the benchmark for counterfactual analysis.

At JRC level, iMAP has pioneered the development of modelling platforms and has inspired to set up a modelling task force and serves as an example of a productive policy-JRC-academia triangle.

2) Scenar 2030— a pre-study for the CAP reform beyond 2020

On 29 November 2017 the European Commission published the communication on 'The future of food and farming' [3] which aims to modernize the CAP with a tailored rather than 'one size fits all' approach, with simpler rules and a more flexible approach.

In this context, the JRC carried out the Scenar 2030 study [4], which analyses the impact on the agricultural sector of stylised scenarios, reflecting the main drivers of the policy debate and thus providing a framework for further exploration of the process of designing the future CAP.

For the analysis of the social, economic and environmental impacts of various options for the next CAP, we employed the iMAP platform models MAGNET, CAPRI and IFM-CAP in an integrated manner covering different spatial scales (global, European Union, Member State, NUTS 2 region and individual farm levels). The use of three different models and their (soft) linkages added complexity, particularly when trying to compare results across models (e.g. different commodity categories).

The scenarios were co-developed in a bottom-up, iterative process with experts from the different directorates in DG AGRI.

The scenarios are not representing real policy options, but underline the potential for changes to current agri-food policies to address societal challenges and demands.

The ‘No-CAP’ scenario - removing all budgetary support to farmers - could lead to strong decline in farm income by 2030, less jobs in agriculture and bring back the EU as net importer of agricultural products.

An 'Income and Environment' scenario - maintaining the CAP budget at its current level with stricter environmental rules - could result in an overall higher income (with some job losses) while avoiding an increase in greenhouse gas (GHG) emissions.

A 'Liberalisation & Productivity' scenario – with a strong reduction in subsidies and a shift to productivity-increasing measures and further trade liberalisation - could lead to a drop in farming income, job losses and agricultural production. The lower GHG emissions would be mostly offset by higher emissions in other regions of the world.

Whatever policy choices are made, smaller farms are likely to be more heavily impacted by changes to regulations and subsidies.

3) Scenar 2030 — impacts in policy process

The JRC report 'Scenar 2030 - Pathways for the European agriculture and food sector beyond 2020' [4] was published, timely after the Communication on 'The future of food and farming' (29.11.2017) [3], on the very day of the 2017 EU Agricultural Outlook conference (18.12.2017), where the JRC Deputy Director General moderated the Session 4 'Enhancing the performance of EU policy and farming' and could also relate to the report.

The main report was accompanied by a Summary report [5] containing the key policy messages, as well as a comprehensive interactive version with infographics [6] prepared within the JRC DataM portal.

The JRC’s scientific insight helped policymakers understand the scope and impacts of potential efforts to ensure CAP is fit for today’s world: a policy that is focused on meeting the challenges of a fair standard of living for farmers, preserving the environment and tackling climate change.

The continued support to the formal Impact Assessment using the same economic modelling tools of the iMAP modelling platform to address alternative scenarios contributed to CAP2020+ legal proposal and to its associated Impact Assessment [7] with economic and environmental data and analysis, published in July 2018.

A systematic tracing of the impacts of Scenar 2030 has not yet been performed. However, there are several examples of impacts (apart from the CAP legal proposal):

- Court of Auditors 'Opinion No 7/2018: concerning Commission proposals for regulations relating to the Common Agricultural Policy for the post-2020 period'
- Spanish Ministry for Agriculture: presentation with very positive feedback
- Several quotations in articles and reports
- Presentation and discussion as different academic fora
- Upcoming report by the Committee of the Regions
- JRC Annual Report 2017.

4) Lessons learned and outlook

Taking the whole process of the support to the latest CAP reform (including Scenar 2030, there are several lessons learned.

First of all, the good and trustful relationship with DG AGRI played a crucial role for the success of the JRC support (there are several notes on Commissioner and DG level). However, important challenges remain, such as time pressure with unexpected requests, sometimes insufficient level of coordination (both internally and with policy DG), data issues, limits on publication of JRC works, the complexity of integration of tools.

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[2] M'Barek R., Delincé J., *iMAP, an integrated Modelling Platform for Agro-economic Commodity and Policy Analysis - New developments and policy support 2012-14,* EUR 27197 EN, Publications Office of the European Union, Luxembourg, 2015, ISBN 978-92-79-47477-4, doi:10.2791/651649, JRC95468

[3] https://ec.europa.eu/commission/presscorner/detail/en/IP_17_4841

[4] M'Barek R., Barreiro Hurle J., Boulanger P., Caivano A., Ciaian P., Dudu H., Espinosa Goded M., Fellmann T., Ferrari E., Gomez Y Paloma S., Gorrin Gonzalez C., Himics M., Elouhichi K., Perni Llorente A., Philippidis G., Salputra G., Witzke H.P., Genovese G., *Scenar 2030 - Pathways for the European agriculture and food sector beyond 2020*, EUR 28797 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-73859-3 (PDF), doi:10.2760/887521, JRC108449

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[6] https://datam.jrc.ec.europa.eu/datam/mashup/SCENAR2030/index.html

[7] https://ec.europa.eu/commission/publications/natural-resources-and-environment

Examples of Europe's marine ecosystem modelling capability for societal benefit

Heymans S. JJ, European Marine Board
Skogen M. D., Institute of Marine Research, Norway
Schrum C., Helmholtz Center for Materials and Coastal Research
Solidoro C., National Institute of Oceanographic and Experimental Geophysics, Italy
Serpetti N., Bentley J., Scottish Association or Marine Science

Marine ecosystem models are an important analytical approach to integrate knowledge, data, and information; improve understanding on ecosystem functioning; and complement monitoring and observation efforts. They offer the potential to predict the response of marine ecosystems to future scenarios and to support the implementation of ecosystem-based management of our seas and ocean. In this paper we highlight the current state of the art in European Marine Ecosystem modelling through case studies using various ecosystem modelling techniques. We build on the case studies given in the European Marine Board's Future Science brief on ecosystem modelling. The case studies include best practice in food web modelling, data analyses, and uncertainty testing in the marine ecosystem off the west coast of Scotland, where climate drivers were included to address the impact of climate change on the future management of fisheries in the area and using an ensemble modelling approach to address structural uncertainties in ecosystem models of the North Sea. A second case study in the Irish Sea shows the use of fishers' knowledge to address data gaps in ecosystem models, and the implications it has for policy uptake. A third case study will address the socio-economic effects of the landing obligation in the Adriatic Sea, where coupled physical, biogeochemical, food web, and socio-economic models have shown the trade-offs that have to be made in that ecosystem.

Finally, a case study from the Barents Sea shows how the implications of the invasive king crabs in Norway has had unforeseen consequences, both negative and positive. All these case studies show the use of ecosystem models to support policy making and assessment.

The Future Science Brief concludes that that there is no single model that can answer all policy questions. In each case the context, specific knowledge and scale need to be taken into account to design a model with the appropriate level of complexity. It is more practical to assemble several models in order to reach the full End-2-End spectrum. This requires a transdisciplinary approach and the inclusion of socio-economic drivers.

Key Recommendations and actions proposed by the Future Science Brief needed to strengthen marine ecosystem modelling capability include:

- Link models to observations and data. Develop models, or coupled models, that can incorporate the full spectrum of ocean data, including biodiversity from microbes to top predators. Ensure data assimilation centers (e.g. the Copernicus Marine Service, EMODnet, etc.) include all existing and emerging data streams. Use models more actively to design ocean observation networks;
- Increase predictability through coordinated experiments and the ensemble approach. Design and run coordinated model experiments, e.g. through a common funding scheme, to model uncertainty and increase model predictability. Further integrate model predictions, historic data and machine learning to generate sensitive adaptive modelling tools that are more representative of the complex interactions of evolving marine ecosystems;
- Make marine ecosystem models more relevant to management and policy. Increase the credibility of models by defining and communicating uncertainties. Couple ecosystem- and physico-chemical- models with socio-economic drivers to include the human dimension. Promote co-design between stakeholders and modellers;
- Develop a shared knowledge platform for marine models and support the development of next generation models for sharing information and capability on marine ecosystem models, building on European initiatives e.g. the pilot Blue Cloud, and the marine modelling framework and associated Network of Experts for ReDeveloping Models of the European Marine Environment;
- Enhance trans-disciplinary connections and training opportunities. Promote training that spans fundamental marine sciences, modelling and policy and develop an online shared knowledge training platform to connect marine ecosystem modellers, share opportunities and promote inter-disciplinarity.

Multi-Objective Local Environmental Simulator (MOLES): model specification, algorithm design and policy applications

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This paper presents the structure, architecture and policy applications of the Multi-Objective Local Environmental Simulator (MOLES), i.e. OECD's new urban Computable General Equilibrium model with selected microsimulation features. The model is tailored to assess the performance of local and national policy instruments that target transport, energy consumption and land use in urban areas. These include, but are not limited to: urban density restrictions, zoning regulations, public transport subsidies, fuel and kilometre taxes, regulations in vehicle ownership and use, congestion pricing, as well as vehicle registration, circulation and parking fees. MOLES assesses these interventions from multiple perspectives, uncovering the potential trade-offs between different policy objectives: environmental performance, economic efficiency, fiscal and distributional balance, housing affordability and other wider benefits. The model is also designed to capture possible synergies between urban planning and transportation policies.

The policy relevance of MOLES is underlined by the inextricable links between urbanisation, economic growth and modern environmental challenges. Urbanisation has been one the cornerstones of 20th century's vast economic expansion. For decades, the uninterrupted economic growth fuelled — and was fuelled by – a constant increase in urban population and the land uptake of cities. Slowly, a series of interrelated challenges that exert pressure on the ability of cities to generate prosperity emerged. Local air pollution and climate change are two of these challenges. Rough measures by OECD (2010; 2015a; 2015b) reveal that 60–80% of the global CO_2 emissions are generated in cities. A growing share of the urban greenhouse gas emissions originate from transport and stationary sources, such as residential heating and cooling. Furthermore, cities span the areas where the largest part of local air-pollution is generated and dispersed, exposing considerable fractions of population to it. The OECD (2012) estimates that the worldwide mortality due to particulate matter ($PM_{2.5}$ and PM_{10}) is expected to increase from 1 million in 2000 to over 3.5 million in 2050. Therefore, to mitigate the overall welfare impact of climate change and air pollution, existing policies that affect economic activity in urban areas have to be streamlined, and new ones have to be conceptualized and developed.

The need to examine policies from an urban perspective is expected to intensify as cities expand. The current trends foreshadow the total prevail of the city. In 2050, about 85% of the population in OECD countries is expected to live in urban areas. The global urban land cover is projected to increase steeply: from 603 thousand km2 it was in 2000 to over 3 million km2 in 2050. Under the business-as-usual scenario, this expansion is highly likely to exacerbate the problem of air pollution. For instance, OECD (2016) projects that, in the absence of more stringent policies, the number of annual premature deaths due to air pollution will increase from 3 million people in 2010 to 6–9 million in 2060. The associated monetized cost will increase from USD 3 trillion in 2015 to USD 18–25 trillion in 2060, with the most affected areas being those densely populated with high concentrations of $PM_{2.5}$.

The model we present in this paper allows the detailed examination of policies that may be part of the answer to these challenges. MOLES is unique in that it combines the internal consistency of a Computable General Equilibrium model with the additional useful details of a microsimulation model. As a CGE model, it represents the value flows between various sectors and stakeholders in a micro-founded way. However, MOLES abstracts from detailed representations of industrial production sectors. Instead, it models with high resolution the real estate development sector, transport providers and urban households, as the behaviour of these agents determines the locational and mobility patterns in an urban area. That is, MOLES differentiates housing markets by location and residential type. It represents urban public transport by several modes and private transport by various vehicle types. That resolution facilitates the examination of policies affecting population density, urban structure and mobility patterns. The CGE nature of MOLES facilitates the exploration of feedback effects of land-use policies on transport demand and of transport policies on the long-run urban development.

The microsimulation elements incorporated in MOLES introduce behavioural margins of high environmental and economic importance. In the model, the decision of whether to own a private vehicle from a certain class of vehicles (e.g. internal combustion engine, electric) is endogenous. Individuals decide the optimal number of trips, their type (i.e. commuting, shopping and leisure) and their destination locations. They also schedule the departure time of these trips across different types of days (working days, bank holidays) and across different periods of one day (e.g. on-peak, off-peak). Most important, travel demand is modelled separately from the ownership decision. That is, individuals select which of the scheduled trips will be realised by a private vehicle, public transport, soft mobility (i.e. walking or bike), or combinations of them. In each case, mode choice is in line with the constraints imposed by vehicle ownership, household location and trip destination. The aforementioned elements enable the analysis of policies that aim to promote greener forms of urban transport. They also facilitate the assessment of policies that alter the within-day travel patterns, by moving part of the traffic from the on-peak to less congested time intervals.

The model has been used by the OECD in a comparative analysis of land-use and transport policy instruments that aim at decarbonising urban transport in Auckland (New Zealand). A second application of the model, focusing on the comparison of policies to curb air pollution in Santiago (Chile), is under way. The presentation will focus on the future applications of MOLES in the contexts of Randstad (The Netherlands), Gothenburg (Sweden) and Istanbul (Turkey).

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Physiologically based kinetic modelling — a bridge between biological science and public health policy

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Mathematical models are an invaluable tool in chemical risk assessment and in medicine, providing a means of assessing the safety and efficacy of chemicals in a more efficient and effective manner, while respecting ethical concerns related to testing on animals and in humans. In particular, modelling can support research planning and regulatory decision making to (a) protect consumers in several areas, such as cosmetics, food and feed, and pesticide use; (b) provide better healthcare through drug development and precision medicine. However, while these approaches are developing rapidly in the research domain, there is a lack of application in the actual implementation of policies on chemical safety and public health. One reason for this translational barrier is the disconnect between modellers and decision makers, with modellers seeking novel ways of elucidating and reproducing real life phenomena, while decision makers are looking for simplicity, reproducibility, cost-effectiveness, transparency and credibility in the models and their results.

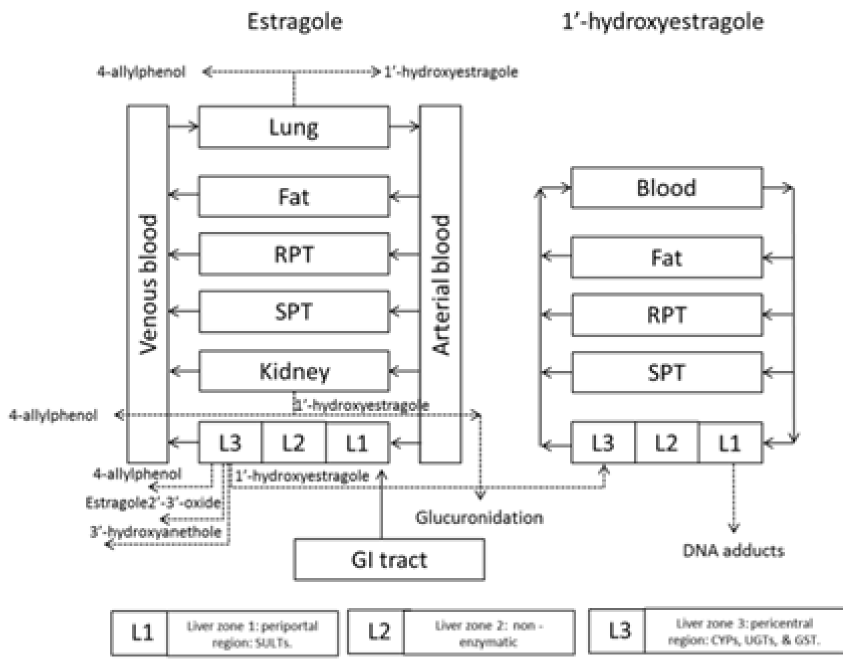
The Joint Research Centre (JRC) is trying to address this challenge by analysing the problem and promoting the use of mathematical modelling in chemical risk assessment and in medicine. Different modelling approaches are being developed, evaluated, used and promoted. Among them are the so called Physiologically Based Kinetic (PBK) models. PBK models describe the body as a set of interconnected compartments, which represent the human organs and plasma, describing the absorption, distribution, metabolism, and excretion (ADME) characteristics of a compound or a mixture of compounds within the body, with several degrees of complexity (Figure 1). Additionally they can be extended to include a description of the interaction of the chemical or its reactive metabolite with the biological target that triggers an adverse effect or efficacious effect.

This presentation will illustrate ways in which PBK modelling can be used to support the safety assessment of chemical products in several regulatory fields (Table 1), as well as in medicine and personalised healthcare. We will provide two illustrative examples reflecting the need to establish safe exposure levels in the context of food safety (estragole, a genotoxic substance that is a natural component of certain foods) and the cosmetics regulation (caffeine). We will also describe a project being led by EURL ECVAM, on behalf of the Commission, at the OECD to promote the international acceptance of PBK models in chemical risk assessment.

Table 1. Regulatory Fields where PBK models can be applied

Field	Regulation
Medical products authorization for human and veterinary use	Regulation 726/2004
Precision medicine	EU policies are in an exploratory phase
Chemical Risk Assessment – REACH	Regulation (EC) number 1907/2006
Pesticides – approval of active substances	Regulation (EC) No 1107/2009
Biocides – approval of active substances	Regulation (EU) No 528/2012
Food & Feed	Regulation (EC) No 178/2002
Cosmetics	Regulation (EC) No 1223/2009

Figure 1. Schematic representation of a PBK model for estragole, a natural component of certain foods (Paini et al., 2012, TAAP, 245(1)57–66).



Parallel sessions 2

Qualitative and quantitative modelling

Room 0.C
26 November
14:00 – 15:30

Integrating qualitative scenarios with quantitative modelling: lessons learned from recent EC foresight projects

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The challenges of integrating qualitative and quantitative approaches in forward looking (FL) exercises have been extensively discussed, which has led to unveiling the multifaceted nature of the main barriers arising. As illustrated e.g. in [1] these range from epistemological consistency all the way to practical implementation of interfaces and data availability. Cultural issues are of the essence, as FL experts and practitioners often belong to either one or the other of two main communities: foresighters whose background is mostly in Social Sciences and Humanities (SSH), and modelers whose tools of the trade originate primarily in mathematics and physics. Of course, SSH have over time incorporated a good deal of quantitative analysis, but models are often seen as a mechanistic, somewhat artificial expedient to feed decision and policymakers with numbers. Modelers, on the other hand, do not always find it easy to recognize the value of purely narrative visions. Economists, in their capacity of social scientists increasingly trained in sophisticated quantitative techniques, would appear to be the natural candidates for bridging the two cultures, and indeed have played a major role towards their integration, although many obstacles still remain. Efforts have been made by qualitative foresighters to include quantitative dimensions in their work, through e.g. DELPHI analyses, or by enriching their narratives with indicators in an attempt to quantify trends, drivers and their potential impact, both however falling short of providing a practicable bridge to modeling. Modelers, on the other hand, are keen to feed their tools with inputs elicited from visions and storylines developed by qualitative foresighters, but the variables that serve as input to their models are not always immediately traceable in the narratives of FL storylines.

This paper discusses lessons learnt from three recent European projects that have explicitly attempted to integrate qualitative scenarios with modelling.

- PASHMINA [2] built four scenarios representing possible shifts in socio-economic paradigms and used models to compare their economic and sectoral performances
- FLAGSHIP [3] developed two long term visions of the European economy, based on the 3-horizon approach, and used models to assess the feasibility and the timing of economic recovery and of the achievement of the COP21 targets.
- FRESHER [4] devised four storylines illustrating contrasted, health-focused scenarios, and used microsimulation modeling to assess their potential impact on the social burden of non communicable diseases (NCD).

What these three exercises have in common is (i) the goal to produce results that are expressed (also) in quantitative terms (so as to speak to policy makers), but reflect deeper and more articulate narratives, not (or less) constrained by the inherent rigidity of models; (ii) an approach that starts by building narrative storylines and then strives to 'translate' them into inputs and assumptions that can be fed to models; and (iii) the belief that the real value of models is not to predict (which is next to impossible when it comes to long term dynamics of complex systems), but to orient, which models can by showing how different dynamics of critical factors (trends, drivers, policies) yield different results. Altogether, the following critical issues emerge.

Discontinuities

Models can perform satisfactorily as long as they do not have to factor in major future discontinuities. This is also the result of the fact that models are mostly (and inevitably) built on the observation and interpretation of a known past, while socio-technical transitions are likely to modify the way systems work today and generate new paradigms that shift away from the known past. PASHMINA, which focused on paradigm shifts, clearly showed that these can be effectively captured by mathematical models — even when substantial deviations from past trends are considered – provided the continuity of pathways and the availability of good data, while models are not equipped to 'automatically' simulate disruptive events or, even less, a substantial change in the nature of the interrelation between variables. On the other hand, a structural change in paradigm entails fundamental modifications in behaviours, which agent-based models can represent and simulate.

Scale

No model can seriously claim to be equally performant at different scales of analysis (e.g. macro, meso, micro), whether this refers to time, space, or/and the granularity of the variables. On the other hand, the ambition of FL is often to analyse trends observed at e.g. global level in order to understand their local or sectoral effects; or, the other way around, to assess the extent that seeds of change detected at the micro scale can be scaled up in the future and with what global consequences. The microsimulation model developed and adopted in FRESHER is a promising attempt of deriving large scale results by simulating behavioural changes at the individual level.

Model flexibility and adaptation

If the modelling framework is 'imposed' at the outset, and narratives built with the sole purpose of providing input to the chosen model, phenomena that are intrinsically difficult to quantify are likely to be ignored. This calls for the willingness and availability of modelers to modify/adapt their equations to account for 'new' phenomena, or for a novel interpretation of existing ones. FLAGSHIP has provided several examples of how an open attitude of modelers in this respect can increase the overall value of FL. As the FLASGHIP scenarios highlighted the growing importance of differentiated R&I investments, new functions were implemented in the NEMESIS model to account for the differentiated performance of R&I spending in ICT, intangibles, and high education.

(Over)simplification

Integrating qualitative and quantitative FL approaches can be seen as an attempt to formalize implicit (or intuitive) relations between subsystems, or variables: scenarios and storylines can suggest/explore the existence and nature of such relationships, while models are tasked with their formalization in order to check they actually stand and provide some measure of their relevance. Along the process, tradeoffs must be found to avoid oversimplification while ensuring that the interactions between the narrative and the equations does not lead to loss or distortion of information. Both PASHMINA and FLAGSHIP made extensive use of the metamodeling approach [5] as a middle ground that preserves the rigor of mathematical formalization while avoiding that the complexity of fully fledged analytics hinders the quality of communication between foresighters, modellers and policymakers.

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Towards absolute measure of poverty in the European Union – A pilot study

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Measuring poverty requires a definition of poverty, a proxy for the level of welfare of individuals (income-monetary and/or non-monetary, consumption, wealth, etc.), and setting a poverty line under which people are considered poor. In Europe, monetary poverty is usually measured with the so-called 'at-risk-of-poverty' indicator (AROP), which defines poverty as the share of people with an equivalised disposable income below the at-risk-of-poverty threshold. The threshold is set at 60 % of the national median equivalised disposable income. As argued by many researchers starting from Sen (1983), a relative poverty indicator (such as the AROP) is a measure of inequality at the bottom of the distribution rather than poverty, as it is unrelated to criteria of need and deprivation. Existing measures focusing on these latter, like that of severe material deprivation (SMD), are not monetary.

This prompts the policy need to improve the current measurement of poverty from an absolute perspective. While this is challenging, there are several reasons why this is important. First, a monetary indicator of absolute poverty would allow contextualising EU social indicators on income poverty and financial stress, could anchor the poverty threshold, and complete the picture. Second, this helps monitoring the adequacy of income support measures and effectiveness of social policies, and better targeting vulnerable groups and local needs. Third, in line with the SDGs, an absolute poverty measurement will further help monitor and translate SDG concerning the eradication of extreme poverty for the EU.

In line with these objectives, the JRC project entitled 'Measuring and Monitoring Absolute Poverty' (henceforth ABSPO) aims to develop a reference-budget based indicator of absolute poverty comparable to existing relative measures, such as the AROP. The project is financed by DG EMPL and implemented by B01 of the Joint Research Centre and will cover a handful Member States as a pilot exercise.

Specifically, the project will develop household-specific poverty thresholds based on adequately priced consumption bundles associated with minimum living standards and adequate social participation. These poverty thresholds will then be confronted with microdata on disposable household income (such as the EU-SILC), to calculate the poverty rate. Importantly, the proposed methodology should be applicable to be used for regular monitoring or EU member states, to be scaled to the EU-level and should enable comparisons across countries and over time.

Because the only methodology tested on the EU scale is that of the EU Platform on Reference budgets (EURB, https://www.referencebudgets.eu), the ABSPO project adopts it as its foundation. In particular, it retains the targeted living standards ('adequate social participation') and the mixed-method approach (using expert inputs, survey data and focus group discussions) embraced by the EURB, but proposes three types of improvements:

1. Extension towards representativeness

The base is an evolutive, modular extension of the EURB methodology whereby appropriate 'customized' poverty lines are calculated for the entire population and all potential households. Specifically, this means modelling also households of old age, poor health and rural living environments, as well as using equivalence scales to cover non-modelled household types.

2. Introduction of additional elements

The additional element in question mostly concerns specific analyses that are only indirectly related to the core exercise, and are aimed at providing valuable context and insights to assess the validity of the methodology. These include, among others,

- cross-checking the results through a survey-based 'fixed-point approach' using EU-SILC;
- collecting survey data on purchasing habits, store choices, price search efforts;
- confronting assumed expenditure patterns with empirical ones around the poverty line.

3. Extension with methodological refinements.

These refinements aim mainly at strengthening the robustness and reliability of the proposed methodology, either by refining certain assumption and using a richer information base (e.g. price statistics for costing baskets).

The delivery and completion of the project, scheduled for June 2021, incorporates inputs from several different actors:

1. A core team responsible for developing the methodology,
2. Country teams that construct the baskets at the local level
3. National statistical offices that provide data access on HH expenditure and prices
4. An advisory board to provide methodological feedback and support
5. An Inter-Service Steering Group that steers the project within the Commission.

The Global Conflict Risk Index (GCRI)

Halkia M., Ferri S., Papazoglou M., Van Damme M. S., Thomakos D., European Commission, Joint Research Centre

The Global Conflict Risk Index (GCRI) was designed by the European Commission's Joint Research Centre (JRC) in an effort to bridge the gap between quantitative conflict risk models developed in academic research institutions and the needs of policy-makers to prioritize actions towards conflict prevention.

JRC's conflict modelling project initiated four years ago and has been developed in collaboration with an expert panel of researchers and policy-makers to become the quantitative starting point of the European Union (EU) Conflict Early Warning System.

The GCRI uses open-source data from 1989 to 2018 for 191 countries worldwide as country-year observations and it considers solely the structural conditions characterising a country, taking into account 25 individual variables in six risk areas, i.e. social, economic, security, political, demographic and geographical/environmental areas. All the variables used in the models have extensively been used as explanatory or control variables in the conflict research literature. The datasets used are all freely accessible on the internet and have been compiled by diverse international organizations such as the World Bank, the United Nations and academic institutions.

Inspired by the existing quantitative conflict risk models, the GCRI is composed of two conflict prediction outputs; the conflict probability and the conflict intensity measured on a scale from zero to ten. Zero represents a no conflict situation while levels one to four cover conflicts that do not include the use of force. Levels five to ten cover violent conflicts, where force is used and results in a number of battle-related deaths involving at least one state actor, depending on the number of casualties and conflicts recorded per year.

Using a logistic regression, we measure the probability of conflict outbreak, while the conflict risk intensity is estimated by a linear regression model. Both estimations of conflict probability and intensity are respectively computed at national (NP) and subnational (SN) levels, depending on the actors involved and the scope of the conflict. Indeed, an NP conflict is defined as a civil war over national power with at least one of the conflicting parties being a national government whereas a SN conflict can occur between a government (one-state actor) and non-state actors, and the conflicting parties typically contest over secession, autonomy, or subnational predominance.

The GCRI hereby encompasses four distinct equations, as to assess and describe the full conflict panorama:

1. Probability of violent conflict at the national level (NP);
2. Probability of violent conflict at the subnational level (SN);

3. Intensity of violent conflict at the national level (NP);
4. Intensity of violent conflict at the subnational level (SN).

Developed at the crossroads of science and EU policy making for conflict prevention, policy-relevant choices are made in the model development stages to support its application. During the modelling stage, this combination creates certain consideration that are different from a pure scientific-investigation context. The GCRI shows that these political-technical considerations can be and are made within scientific bounds, safeguarding scientific rigour as well as objective policy support.

According to our knowledge, the GCRI is the only model that calculates both the probability and intensity of the forecasted structural risk of a country to engage in armed conflict at national or subnational level.

This differentiation between an NP and SN model translates the type of conflict to expect and informs policy-makers on the suitable measures to be undertaken for conflict prevention.

While the GCRI remains firmly rooted by its conception, construction and modelling methods in the European conflict prevention Agenda, it is validated as a scientifically robust and rigorous method for a baseline quantitative evaluation of armed conflict risk.

Modelling stakeholders knowledge and requirements on soil multifunctionality across EU

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Policy making on agri-environmental themes across EU is challenging, especially when it is required to help the local stakeholders facing daily soil health and land management issues. Simultaneously society is required to face food security while safeguarding natural resources with little time left for policy engagement. For this reason researchers' challenge is to bridge stakeholder's knowledge and needs on soil multifunctionality and land management with policy makers. The LANDMARK multi-actor project ran 32 workshops across five EU MS countries covering different pedo-climatic conditions and land uses. The purpose was to harvest existing knowledge and requirements across levels: from a) local farmers and farm advisors; to b) regional/national stakeholders and c) EU policy makers. Information have been collected, harmonized and included: empirical knowledge and perceptions of soil quality, common actions and valuable tools for land management, indicators for monitoring soil functions, policies and guidelines that could optimize the supply and demand of a range of soil functions. But the analysis and comparability of this high amount of qualitative results in a comprehensible way, represented a methodological problem. This has been resolved performing a Multi Criteria Decision Analysis (MCDA) to generate two qualitative multi-attribute decision models (MADM) using DEXi modelling software. Two DEXi models on knowledge and needs on soil and land management have been developed and the workshop results used as input data to model. The modelling exercise was able to represent a large qualitative source of information harvested in four different languages in a condensed, visual and understandable way. The modelling results captured the different EU stakeholders' perceptions, priorities and concerns across scales and stakeholders' level. Concepts and terminology about soil quality and soil functions differ regionally. Implementation tools and management techniques reflect the different pedo-climatic conditions. Modelling results showed that all the 470 stakeholders engaged have a medium to high understanding of soil multifunctionality, but there are knowledge gaps in terms of soil data, programmes and shared discussions, application of policy instruments. Further, the results showed the contrast between the stakeholder levels: farmer and farm advisors are focussed on tools for improving local knowledge, while multi-stakeholders discuss policies and research solutions at regional and national level. Focusing on the second model the community identified as high requirements the following: 1) financial incentives to change soil and land management and commodity risk, 2) clear, independent and validated information on soil-friendly management techniques, 3) high quality advice for farmers, 4)farmers' discussion groups, 5) training programs especially for farmers and farm advisors, 6) funding for applied research and monitoring systems of soil functionality, as well as 7) more soil science in education. The results of this modelling exercise provide important inputs not only at EU policy agri-environmental making but also in for bilateral initiatives such as EIP-AGRI. Furthermore it can be incorporated in local and regional initiatives such as training programmes, discussion groups and education courses. In order to ensure a responsible and transparent use of data collected for policy support the workshop information, models and modelling results are available in an online platform freely accessible to users (http://landmark2020.eu/stakeholders-platform/). This decision support modelling methodology can support evaluation of alternatives and decision making on soil and land management issues. The potentiality of this context specific and novel approach it is not only to solve problems of integration of opened and closed ended surveys but also the potential adaptation and use of the methodology for other EU policy areas dealing with sustainability assessment.

The work is part of the LANDMARK (LAND Management: Assessment, Research, Knowledge Base) project, funded by the EU's Horizon 2020 research and innovation programme under grant agreement No 63521.

The politics of models: socio-political discourses in the modelling of energy transition and transnational trade policies

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Energy policy and transnational trade policy are two main areas of 'modelling for policy'. Models in these areas fulfil a variety of functions, from the identification and analysis of societal problems to the examination of different policy instruments and the assessment of the impacts and costs of planned and implemented policies, yet they also serve to justify and legitimize public action. In this role, models are not neutral tools, simply providing orientation and answers to (exogenously given) societal or political questions but have performative effects for socio-political discourses. Modellers adopt and reframe policy questions, they make relevance decisions and assumptions regarding parameters, factors and scenarios to include, and, in some cases, derive recommendations and options for societal and political actions.

In our presentation, we explore and discuss the (re)production of socio-political discourse and narratives in computational modelling and simulation in the two domains, transnational trade policy and energy transition. Methodologically, we build on quantitative and qualitative analysis of academic articles. We developed two broad corpora that include scientific articles and reviews on modelling developments and/or applications and respective results in relation to the two domains. By the means of bibliometric analyses (inter alia, citation, co-citation, bibliographic coupling analysis) and text mining approaches (i.e. co-occurrence analysis and topic modelling, based on abstracts), we first explore the main subjects and socio-political semantics of modelling in the two domains separately. Expectedly, modelling energy system transitions strongly relates to discourses of climate change and the decarbonization of the energy system. This includes the socio-political narrative on CO2 reduction targets with specific time frame (e.g. until 2020/2030/2050) that serves as an important motivation and legitimization of energy system modelling. Yet, energy models are also related to another policy discourse, revolving around the provision of energy infrastructure to rural, low income countries or geographically isolated regions, which have no well-established energy system so far. The normative embedding is different in these two examples. One of them is rooted in a globally acknowledged environmental crisis (climate change) and the second is based on the 'right' of having access to energy (although it is not an acknowledged basic human right, discussions exist which address this). In our second case, i.e. modelling in relation to transnational trade policies, the text mining analyses expectedly reveal a strong dominance of the free trade discourse, including references to various free trade agreements. Beyond that, a range of further policy objectives and narratives are present and reoccurring in the modelling community, notably welfare, labour as well as poverty and inequality. As a time overlay analysis suggest, more recently trade policies are linked to environmental and energy issues. In our presentation, we will discuss these policy narratives and their linking to specific modelling approaches in more detail.

Notably, the different policy discourses and narratives feature a strong geographic component in both modelling domains. Thus, we find thematic clusters around specific countries or regions (notably Europe, China, India) as well as groups of countries or regions (less developed, rural regions, islands). For example, we observe that the climate change discourse is strongly linked to modelling energy transition in Europe,while the energy security and development discourse is linked to less industrialized countries and rural areas. Bibliometric mapping (citation, co-citation and bibliographic coupling) further indicates that these discourses are nevertheless predominantly driven by Western countries (particularly the U.S. and Europe). This leadership is reflected in the overall numbers of publications per country as well as the most relevant and central documents (in terms of citations and positioning in the network maps) in the respective corpora. This geographic imbalance raises questions about the political implications, particularly when considering that less-industrialized countries are frequently object of modelling in the domains energy transition and trade policy.

We deepen this overview analysis with a qualitative analysis of selected key articles from each area. The qualitative analysis allows additional insights in how policy issues and missions are adopted and transformed in modelling exercises, how societal visions and ideas find their ways into models and scenarios and whether and how ultimately modelling results are used to address specific policy actors or decisions. We find quite distinct patterns across and within the two areas. Our analysis shows that socio-political aims and discourses frequently serve as the motivational background of modelling exercises, ranging from rather implicit and abstract reference to existing social and political discourses to explicit reference to political aims and strategies. Beyond providing the motivational background, concrete policies may feed into modelling in different ways, for example as the basis for different scenarios in a simulation or end points for which optimized solutions are sought. Such policy input might be defined by the researchers themselves or might base on the direct involvement of policy-makers (or other stakeholders) in the modelling process. Particularly, in the latter case, we analyze how modelers apply distinct strategies of boundary management to present their results as policy-relevant, while avoiding suspicion of politicization. Overall, with our analysis of scientific modelling discourses, we illustrate how the 'politics of models' does not only concern their use at the science-policy interface, but is already inscribed in their development, application and scientific presentation. These analyses may help experts, policy-makers and the public to better assess the knowledge claims and evidence politics of computer modelling.

Parallel sessions 3

Scenarios, model linkages and data for policy 2

Room 0.A
26 November
16:00 – 17:30

Combining micro and macro simulations to assess the distributional impacts of energy transitions. Evidences from the French national low carbon strategy

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Redistributive consequences of environmental policies constitute a major issue for the public acceptability and hence political feasibility of the transition towards a sustainable economy. The direct regressivity of environmental policies, especially carbon taxes — regressive taxes are inversely proportional to wealth — is established (Combet, Ghersi, Hourcade, & Théry, 2009; Rausch, Metcalf, & Reilly, 2011). Accounting for it requires energy-transition models to consider income and consumption heterogeneity more than they currently do (Rao, van Ruijven, Riahi, & Bosetti, 2017; Sánchez, 2018). Moreover, recent demonstrations in France have underlined that rising fuel taxes mostly affect the income of workers living in low-density areas. This is a reminder that the distributive impacts of energy transition policies result not only from income inequalities but also from other socio-economic features that influence the residential and mobility energy consumptions of households (Büchs & Schnepf, 2013).

Our paper's research objective is precisely to investigate what socio-economic features drive the short to mid-term distributive impacts of the French government's National Low-Carbon Strategy (Stratégie Nationale Bas Carbone, SNBC). To that end, we develop an original methodology that combines micro-simulation and computable general equilibrium (CGE) techniques to produce economic outlooks both consistent at the economy-wide level and disaggregated across several thousand household types characterised by several hundred socio-economic characteristics.

Our CGE model, IMACLIM, is a static hybrid model focused on reconciling national accounting and energy flows (De Lauretis, 2017). We calibrate it on an original economy-energy dataset in the form of a 14-sector input-output table produced in collaboration with the French Environment Agency for 2025, 2030 and 2035 horizons.

We combine IMACLIM with microsimulation as a 3-step procedure. First step is to model households' expenses trends following price and income changes. Second step is accounting for trend-breaking policies targeting the improvement of the thermal efficiency of French homes and the electrification of private transportation. We estimate for each household carbon-abatement potentials for housing renovation or electric vehicle (EV) purchase. We bound the possible distributions of these investments among households by an optimistic scenario favouring high-potential households and a pessimistic scenario where investors are already energy-efficient. Third step is micro-accounting through household reweighting using marginal calibration against control aggregates (De Lauretis, 2017). Reweighting ensures consistency between micro and macro distributions of socio-economics characteristics.

The convergence of the two numerical systems lies in an iterative exchange of variables between the micro- and macro levels. The 3-steps microsimulation procedure computes the reaction of the aggregate budget shares of households' expenditures to the income and relative price variations computed by IMACLIM. IMACLIM produces its economy-wide outlook under constraint of these budget shares. Iterating the modelling sequence results in numerical convergence towards economic outlooks consistently combining the integrative quality of general equilibrium analysis and the socio-economic depths of the household database backing the micro-simulation model.

Four simulations, each one removing one package of policies concerning carbon tax, EV and housing renovation, allow us to quantify different policies' influence on vulnerability — both fuel and monetary poverty.

In particular, we assess whether energy-efficiency policies are adequate to bridge the gap between the poor and the rich in the transition. Gini and Atkinson index are national-level vulnerability indicators to compare distributive performance of scenarii. We determine horizontal inequalities based on socio-economics features through a principal component analysis regressing fuel vulnerability indicators (Berry, Jouffe, Coulombel, & Guivarch, 2016; Hills, 2012) and the share of constrained expenditures in household budgets. We then use multidimensional analysis to decompose inequalities among most prominent features (Farrell, 2017).

Our original model is able to test a large variety of compensatory measures. Ex-post policies are mainly recycling of carbon tax revenues in the form of per capita rebate from Social Security, an increase in all social benefits (Cronin, Fullerton, & Sexton, 2018) or a simple flat transfer targeting low-income households (Berry, 2017; Douenne, 2018). Potentially popular measures would be to lower the marginal tax rate on income, which could trigger Double Dividend (Rausch et al., 2011), or to grant tax carbon rebates based on the mean damages among a group of similar households.

The dataset is still under construction but results will be available in due time for the conference.

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Energy security assessment framework to support energy policy decisions

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Security of energy supply plays a considerable role in the economic growth and social welfare in any country and is an integral part of the Energy Union (EU) strategy [1]. Unexpected disruptions in energy systems can have both an economic and social cost. As a result, energy security has become a key theme not only in the EU, but also worldwide long time ago. The latest strategic European Commission's (EC) policy documents [2] emphasize the importance of diversifying sources of energy and ensuring energy security as well. However, to support energy policy-making, the framework for energy security assessment can be seen as a necessary measure.

The main objective of the presented framework is the assessment of energy security for analysed countries using energy system modelling approach. The framework is based on the mathematical model for future perspective of energy security coefficient (ESC) for different development scenarios of energy systems. It allows to assess energy security in terms of energy systems resilience to disruptions and consists of several steps, each of which can be described by the following models:

- probabilistic model for the formation of stochastic disruptions of energy system and their parameters;
- mathematical optimisation model for modelling of disrupted energy system scenarios;
- energy security metric employed to measure energy security via energy security coefficient, which indicates the level of energy system resilience to disruptions.

The first step is designed to the identification of threats to energy security. Each threat can realise in any energy system disruption that could do potential damage to the energy system. Since the threats and disruptions are of a stochastic nature, the probabilistic model is used for determination of probability distributions for disruption parameters, such as the start, duration and extent of disruption, interruption or complete cut-off of energy supply, price increase of energy sources, availability of technology and other. This enables to generate a set of disruption scenarios that is used for modelling of energy system.

In the second step, various scenarios of prospective development of energy system are modelled using energy system model implemented in the Open Source Energy Modelling System (OSeMOSYS) [3]. These scenarios are modelled with a set of stochastic disruption scenarios, where values of disruption parameters are determined using the above mentioned probabilistic model. As the main outcome of this model is disruption consequences that include the energy cost increase and possible amounts of unserved energy due to disruptions.

In the third step, ESC is determined as an integral characteristic of disruption consequences: unserved energy and energy cost increase. ESC is used to measure energy security defining its level in the scale from 0 to 1. It enables to compare various energy development scenarios in terms of energy system resilience to disruptions and to assess the impact of individual energy projects on energy security.

The framework was applied to energy system of Lithuania to measure how ESC relates to different energy development projects in the future perspective within three scenarios. One of the most important energy security assurance requirements is the capacity of the energy system to resist possible disruptions. Fig. 1 demonstrates the average ESC in each year for analysed scenarios.

In 2015, liquefied natural gas (LNG) terminal has had a significant impact upon Lithuanian energy security, as it diversifies the supply of natural gas and has removed the threat of total dependence of Lithuania on natural gas supplied from Russia, for which the country had to pay a monopoly price; besides, the threat of political pressure has also been softened.

New power connections with Sweden and Poland in 2016 have exerted a positive impact upon ESC mainly due to improved resilience of power system to electricity supply and import interruptions (diversification of electricity import and market).

In 2020, Gas Interconnection Poland-Lithuania (GIPL) is foreseen as one of the projects which can contribute to the assurance of national energy security. Furthermore, in 2016-2021 some old natural gas and oil technologies end exploitation. For this reason, the ESC does not reach higher level in 2020 as can be expected due to GIPL. On the one hand, new gas interconnection diversifies natural gas supply sources and routes, integrates gas market of isolated Baltic States into the common EU gas market, ensures natural gas supply security and reliability in Lithuania and may contribute to the rational use and availability support of LNG terminal. On the other hand, with the closure of old power units energy system has become more vulnerable due to the provision of proper electricity reserve and technical disruptions.

A significant increase of ESC is observed in 2025, when the synchronization of Estonian, Latvian and Lithuanian power systems with the European Continental Network (ECN) is implemented and related to that the second power connection line with Poland is opened. Disconnection of the Baltic power system from synchronous work with the IPS/UPS and synchronization with the ECN is mandatory measure for energy security assurance in the Baltic States. This would prevent from a possible total 'black-out' of the power network of the Baltic States or unreliable work of the network and would remove possible geopolitical threats from the Eastern countries, which might manifest themselves through disruptions in the power system. The frequency of the electricity systems of the Baltic States is currently controlled from a central dispatch centre in Russia. Such possible geopolitical threat would be eliminated after the synchronization. Once the Baltic States synchronize with the ECN, they will not only operate their systems on that region's frequency, but also apply its common rules. Additional energy security measures might be increasing the capacity of power lines with other countries, RES development or other.

The developed framework might be seen as a supporting tool for energy policy makers to see an integrated picture of energy security measures.

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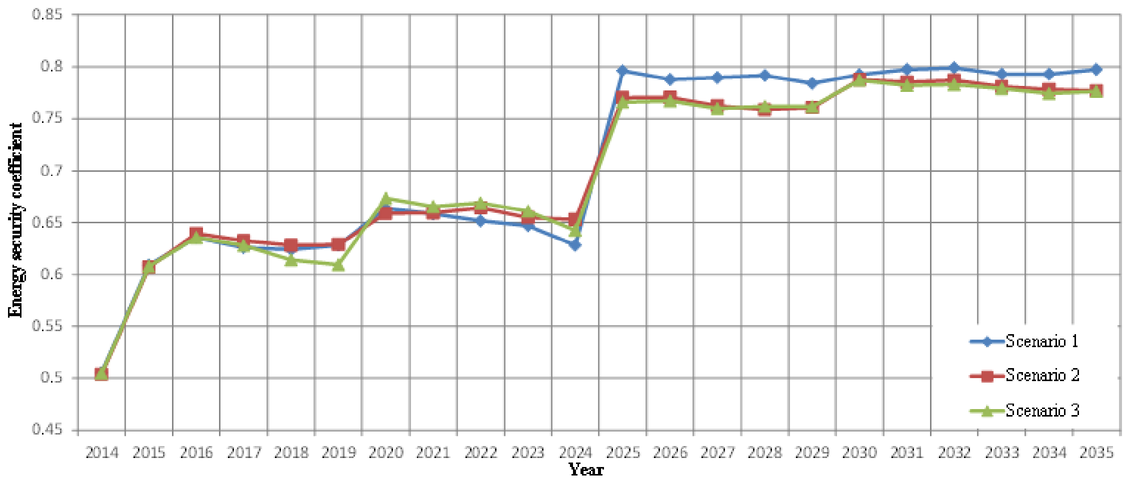
Fig. 1. ESC in the analysed scenarios for energy system of Lithuania



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Decarbonising transports in Portugal up to 2050: possible pathways

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Portugal publically affirmed its firm commitment to be neutral in GHG emissions by the end of the first half of the century, during the twenty-second session of the Conference of the Parties (COP 22). The Paris Agreement (UNFCCC, 2015) opened a new phase in global climate action identifying the need to achieve carbon neutrality by the middle of the 21st century as a condition to ensure that, by the end of this century, the increase in the global average temperature is held below 2 °C, compared to pre-industrial levels, and to pursue efforts to limit the temperature increase up to 1.5 °C. Reaching this goal is particularly challenging for the Portuguese transport sector which accounts for 16.2 million tons of greenhouse gases (GHG) emissions, approximately 23% of the country total, roughly the same emissions level as power generation. Most emissions (96%) are due to road transport subsector, being the remaining share associated with other mobility forms (i.e. aviation, railways and navigation). Transports are also contributing for local Air Quality (AQ) problems in cities, especially due to NO2 and PM10 which tend to exceed AQ limit values in some traffic hotspots.

The Portuguese Roadmap for Carbon Neutrality (RNC2050) was developed to find possible pathways for all Portuguese socioeconomic sectors to achieve zero net carbon emissions by 2050. The RNC2050 aims to explore feasible technologies, while pursuing economically viable and social acceptable strategies to attain national decarbonisation in the whole sectors. As such its results are transversal to all economic sectors from less problematic emissions to more complex subsectors, like road transport decarbonisation.

In the RCN2050 context, three distinct core socio-economic scenarios have been designed, describing three different visions of the near future country's development (e.g., production profile, population evolution, spatial planning, energy and climate). These visions were produced for the period 2020-2050. The configuration of these different trajectories resulted from prospective analysis, based on macroeconomic, demographic and technological scenarios, and also on active participation of several stakeholders from different sectors. The prospective analysis focused on the energy system, buildings, mobility and transport, agriculture, land use and forests, and waste, being considered options and different integration levels of circular economy (transversal to most economic sectors).

The technological linear optimization model TIMES_PT was used to evaluate the future penetration of different cost-effective technological mobility options in distinct scenarios. Several updates were added to the model technology database being the inclusion of shared and/or autonomous vehicles one of the most important. The TIMES_PT model represents the Portuguese energy system and its possible long-term developments. The model incorporates a high number of modern technologies related with the different components of the energy systems. They are characterized in terms of technical (e.g. energy efficiency, lifetime) and economic (e.g. investment and operation costs) features. The mobility demand for each scenario was defined with a bottom-up approach, considering urban and peri-urban transport conditions, smart city expected developments, and impacts of mobility megatrends. Different scenarios were defined considering distinct levels of future configurations and mobility trends (i.e. autonomous vehicles and sharing schemes). A soft link was developed to estimate the impacts of carbon neutrality scenarios on air pollutant emissions.

One of the main findings is carbon neutrality technical viability in Portugal by 2050. Emission reductions imply significant levels of renewable sources on final energy consumption, reaching 85–90% by 2050, in particular in the production of electricity, and consequently on road transport, which reaches full electrification by 2050. Transport and mobility is the sector with the greatest energy profile transformation, going from the most representative sector (37%) to the one with least expression in terms of final energy consumption (19%).

Results highlight a fast decarbonisation of transport sector (-98% of GHG emissions in 2050, compared to 2005), even with higher demand for mobility in all modes. Traditional fossil fuels are progressively replaced by electricity, biofuels and H2 (accounting for 93% of the energy consumption in 2050). Electricity is preponderant in most of the means of transport (70% of the energy consumption in 2050). Electric mobility is a key driver for full transport decarbonisation, but shared mobility can produce additional efficiency gains.

The passenger mobility demand increase is ensured both with more public transport and with the generalization of individual shared and/or autonomous electric transport. Buses have a great potential for electric mobility, which accounts for about 1/3 of demand in the decade 2030–2040 and 2/3 of demand in the decade 2040–2050, with the remaining consumption being assured by biofuels in 2050. Shared mobility plays a major role on this energy transition (although uncertainty remains in deployment trajectories) highlighting part of the need for circular economy approaches also in the mobility sector. Regarding heavy duty transport, the introduction of new fuels (H2) or technologies (electric road systems) depend on the implementation of basic infrastructure. Major efficiency improvements, in all mobility modes, cause reductions in energy intensity between 2005 and 2050 (of 74% of energy consumed per pkm and of 83% of energy consumed per tkm).

In 2 of the 3 designed scenarios Portugal reach carbon neutrality by 2050. This goal brings also strong benefits for air pollutant emissions as important co-benefits. Major emission reductions in transport sector are accomplished for NOx (95%) and CO (99%) in 2050. The 2030 air pollutants targets fulfilment is highly dependent on the expected electric vehicle penetration by that horizon.

Modelling the macroeconomic and employment Impacts of future mobility disruption Scenarios

Tamba M., Saveyn B., Krause J., Grosso M., Duboz A., Ciuffo B., Fana M., Fernandez-Macias E., European Commission, Joint Research

1. Introduction

In the context of digitalisation and decarbonisation, the transport sector will undergo radical transformations in the decades to come (Alonso Raposo et al., 2019). In particular, three key trends hold a significant disruptive potential for road transport: Automation, Connectivity and Electrification (ACE). In this study, we examine how these new trends in road transport may have wider societal implications for the European Union, for example in terms of jobs and CO2 emission reductions. Using an energy-environment-focused dynamic Computable General Equilibrium model, we simulate scenarios with varying deployments of ACE out to 2050 to analyse the potential macro-economic, employment and environmental impacts in a global context.

2. Methodology

The modelling is based on the analysis of three main scenarios, designed to capture alternative hypothetical evolutions of road transport, and to isolate the impact of electrification from those of automation and connectivity:

- The baseline includes limited electrification and no penetration of connected autonomous vehicles (CAVs) in road transport, in line with the modelling produced for the EU strategy for long-term greenhouse gas emissions reduction (Keramidas et al. 2018).
- In an electrification scenario, we assume a substantially larger electric vehicles (EV) penetration, both in freight and passenger transport, in line with the EU long-term strategy to limit global warming to 2C.
- An automation-connectivity scenario, where connected and autonomous vehicles (CAV) are assumed to enter the vehicle fleet as early as 2020 and reach high penetration by 2050.
- A scenario combining electrification and automation-connectivity.

These scenarios include how the penetration of these technologies could also alter the operation of the stock, e.g. in terms of fuel consumption, maintenance costs, etc. We analyse these scenarios using the JRC-GEM-E3 model, a global multi-sectoral general equilibrium model, extensively used in EU climate policy research (see for example Vandyck et al. 2018).

The JRC-GEM-E3 model is modified in two important ways. First, the manufacturing of vehicles is split between two sectors of activity: the existing automotive sector and the manufacturing of electric vehicles. The cost structure of this new vehicle manufacturing sector is derived from engineering studies of components to capture the difference in production processes compared to conventional internal combustion engine vehicles of today. Second, the deployment of vehicles is captured through the dynamic adjustment of the vehicle-related capital stock on the production-side of the economy and of the vehicle-related durable good consumption on the household side; shifting from conventional manufacturing to the new vehicle type. Moreover, changes induced by the deployment of new vehicles, from fuel switching and fuel efficiency, to reduced labour intensity, to varying maintenance requirements, are introduced in the model as changes in input-output coefficients, and changes in the household consumption matrix, which relates industrial outputs to consumption goods such as transportation. For example, the consumption matrix can be modified to adjust fuel use and fuel type within the operation of a private vehicle. These operational shifts are endogenously linked to the deployment of new vehicles in the stock. A combination of energy system models scenario modelling results and literature review are used to quantify and parameterise these changes.

We use the extended model to examine the macro-economic and environmental impacts of these mobility disruption scenarios. In addition, a number of sensitivities are conducted on key assumptions (e.g. battery costs reduction and comparative advantage in trade, labour input requirements). Finally, modelling results are used to further investigate the impacts of ACE on jobs, linking the sectoral employment results to a new framework disaggregating the employment structure by occupation, skills and tasks.

3. Results and policy relevance

We analyse the general equilibrium effects of the scenarios described above in a global modelling framework with endogenous international trade, explicit supply chain representation and accounting for CO_2 and other GHG emissions. The modelling work is ongoing and final results will cover both aggregate indicators such as GDP, exports and emissions but also identify sectoral implications (output, investment, employment).

These results will provide relevant insights for the policy questions currently under investigation in the European Commission at the intersection of transport, climate and energy issues, for example in the context of the Low-Emission Mobility Strategy (European Commission 2016). The study also builds capabilities to assess policy initiatives to foster employment and foresee and mitigate any possible negative social impacts. In particular, it will provide a first analysis of the potential economy-wide impacts of these new transport technologies in the EU, while the focus on employment will enable a deeper understanding of the transition required in terms of occupation and skills.

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Global trends of methane emissions and their impacts on ozone concentrations

Van Dingenen R., Dentener F., Crippa M., Guizzardi D., Janssens-Maenhout G., European Commission, Joint Research Centre

Background

Methane (CH_4) is the 2nd most important anthropogenic greenhouse gas after carbon dioxide. Since the pre-industrial era, methane concentrations have more than doubled, and at present sources related to human activities are about 50% larger than natural ones. After a period of stagnation, methane concentrations are increasing again since the last decade, and by 2020, may reach levels that match the most pessimistic projections used in the IPCC AR5 report. It is often forgotten by policymakers that methane is also an important precursor of ozone (O_3) in the troposphere. Ozone itself is a greenhouse gas and short-lived climate forcer, but it is also an atmospheric pollutant responsible for harmful impacts on human health and damage to crops and vegetation and for which air quality standards have been established. In various parts of the world environmental policies aim to reduce ground level ozone, but there is a risk that increasing methane emissions will counteract those regional efforts. Because methane stays about 10 years in the atmosphere, chemical mechanisms that lead to widespread ozone formation involve methane sources from everywhere in the world and mitigation efforts must become a global goal. Methane mitigation is therefore an issue with relevance across policy fields, requiring supra-national coordination. Here we explore for an ensemble of future scenarios, the impact of projected methane emission trends until

2050 on background ozone, and its impacts on human health and crop yields.

Method

Understanding the methane contribution to present and future ozone levels, as well as the multiple co-benefits of mitigation measures requires a global modelling approach. The JRC Fast Scenario Screening Tool (TM5-FASST) is a reduced-form source-receptor air quality model for the global domain (European Commission, 2016; Van Dingenen et al., 2018). The tool uses emission-normalized pollutant concentration response fields (including all ozone precursors) that were pre-computed with the full chemical transport model TM5 (Krol et al., 2005). TM5-FASST linearly scales these normalized response with actual CH_4 emission changes to obtain global CH_4-induced ozone concentration and ozone exposure metrics at a 1°x1° spatial resolution. The exposure metrics are then used to compute impacts on human health and agricultural crops. We apply the TM5-FASST screening tool to evaluate an ensemble of emission scenario families for the years 2030 and 2050, each family represented by a low mitigation, a stringent mitigation and a middle-of-the road pathway.

Results

Unabated, global anthropogenic CH_4 emissions could increase by 35 to 100% (from ca. 330 Tg CH_4 yr 1 in 2010 to 450–650 Tg CH4 yr 1) by 2050 for a range of pessimistic scenarios. For these pessimistic scenarios health-impact weighted O_3 could rise by 2–4.5 ppb globally, causing 40,000 (+12%) to 90,000 (+26%) more O_3 premature deaths compared to present.

Intermediate CH_4 emission reduction scenarios, for instance those compatible with the emission reduction commitments included in the nationally determined contributions of the signatories of the Paris Agreement, would bring down CH_4 emissions substantially compared to the pessimistic scenarios, with the exposure of the global and European population to ozone remaining at 2010 levels.

By contrast, optimistic sustainability scenarios, such as those that target the 2° Paris Agreement goals, projected CH_4 emission reductions of up to 50%, to 180–220 Tg CH_4 yr 1 CH_4 by 2050. Such scenarios assume structural changes in the energy, waste and agricultural sectors, together with the implementation of all currently available emission abatement technologies. O_3 may decrease by 2 ppb (compared to 2010), saving worldwide 30,000 (-9%) to 40,000 (-12%) lives.

The maximum CH_4-O_3 mitigation potential would be given by a situation without anthropogenic CH_4 emissions: global ozone damage to crops would be reduced by 26%, and O_3 related mortality by 20% compared to present day ozone impacts. For Europe we estimate a potential damage reduction by 40% and 34% for crops and health respectively. In terms of emission reductions, the optimistic scenarios reach about 2/3 of this maximum potential.

Conclusions

Impacts of short-lived air pollutant emissions ($PM_{2.5}$, NO_2) are strongly linked to the emission location and emission controls are largely driven by countries' self-interest. In contrast, the transboundary nature of the air quality impacts of CH_4 emissions justifies international cooperation to reduce these emissions. This cooperation may be found under the UNFCCC Paris Agreement, or regional conventions such as the UNECE Convention Long Range Transport of Air Pollution (see Maas and Grennfelt, 2016), or the Arctic Council. Aakre et al. (2018), using the TM5-FASST tool also utilised in this work, argue that collaborations between 3 to 6 key regions ('clubs'), may realize a substantial portion of the global mitigation potential, and overcome some of the difficulties associated with global agreements.

In this context the availability of scientific assessment tools, encompassing the full cycle from CH_4 emissions to impacts as well as the evaluation of economic costs and benefits is essential in building trust and confidence between the collaborating partners.

CH_4 and O_3 are both important greenhouse gases. By 2030, ambitious CH_4 emission reductions, of which many come at zero or negative cost, could close 10 to 20% of the emission gap identified by the United Nations Environment Programme (2019) between the total commitments in the national determined contributions of the signatories to the Paris Agreement and the emissions needed to reach an end-of-the century 2 °C target.

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Parallel sessions 3

Integrated modeling: the case of the Food-water-energy-environmental NEXUS management under uncertainty and risks

Room 0.B
26 November
16:00 – 17:30

A strategic decision–support system for strategic robust adaptation to climate change and systemic risks in land use systems: Stochastic integrated assessment GLOBIOM model

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Climate change and variability are expected to have significant and highly uncertain impacts on agricultural production and the utilization of natural resources, affecting food, water, environmental, and energy (FWEE) security at national and regional levels, with the potential for world-wide spillovers. Different regions will be subject to different types of exposure. To ensure adequate agricultural production and thus food security at the level of EU countries and main economic regions, an analysis of local agricultural adaptation strategies have to be designed and implemented to tackle uncertainties and risks in a robust way: such strategies include decisions on governmental regulations, investment in and reform of water management, land use practices, agrofood production patterns, and food trade regulations (European Commission 2009). It has been recognized that climate adaptation is a major concern of the Common Agricultural Policy (CAP) of the European Union (EU). In the proposed CAP regulations for 2014–2020, adaptation has gained great prominence, with 'the sustainable use of natural resources and climate action' being one of the core objectives.

In our talk, we discuss the on-going work at IIASA contributing to FP7 Project 'Economics of climate change adaptation in Europe' (ECONADAPT), Horizon 2020 Project 'Co-designing the Assessment of Climate Change costs' (COACCH), and Framework Service Contract — Ecosystems Support for Copernicus and EU Space Policy. The projects focus on providing user-orientated decision-support methodologies and evidence relating to the analysis of uncertainty and inherent risks, and economic appraisal criteria to inform the robust choice of adaptation actions. The historical performance of land use systems (e.g. their impacts on climate change, water availability and quality, soil quality and erosion, and biodiversity) shows that a proper analysis of interdependencies, synergies and trade-offs between uncertainties, risks, policy measures and systems' responses within and beyond land use systems, is crucial for sustainable land use systems development.

In the absence of evidences on potential systems' performance in new uncertain conditions (i.e. climate change and increasing weather variability, structural changes and increasing systemic interdependencies), the main challenge is to design new systems and robust policies, which enable long-term mutual stability of the systems irrespective of the future uncertainty scenario. Therefore, in the presence of inherent uncertainties, the main issue is about designing robust solutions, which leave systems better-off under all potential scenarios. As the variety and the interconnections between LUS increase, the design of robust solutions has to be based on the analysis of complex systemic interactions and risk exposures evaluated with respect to FWEE security targets.

Our talk discusses the two main issues. First, we summarize the results of the stochastic GLOBIOM model studying synergies and trade-offs among different measures of the new Common Agricultural Policy (CAP) with the aim to identify the principles that can ensure the most effective distribution of CAP funds to achieve optimal climate change adaptation in the face of inherent uncertainty and risk. The results demonstrate numerically that a proper interdependent analysis and appraisal of the EU CAP measures under uncertainty and risks can speed-up the mainstreaming of climate change uncertainty, risk management approaches, and robust actions within the CAP implementation plans. The benefits of robust decisions are estimated with the so-called 'Value of Stochastic Solutions'. The recommendations of the stochastic model have been summarized in deliverables to the EU Commission.

Second aspect of the discussion focuses on the improvement of knowledge about global change processes though advanced data and information access services such as e.g. COPERNICUS. Any discussion of a policy implementation must be coupled with the problem of determining the level of knowledge about uncertainties and associated risks, and the appropriate 'security' level reflecting strategic global and local food-water-energy-environmental norms and regulations. Continuous feedback from the environment is one way to help reduce uncertainty. The potential for adaptive improvement of our knowledge (or learning) about inherent uncertainty in combination with strategic robust decisions can considerably reduce (or increase) the costs of required adaptation and risks management. Using stochastic GLOBIOM model, we illustrate how to provide an integrated assessment of short- and long-term socio-economic and environmental quantifiable and non-quantifiable benefits of improving the knowledge about uncertainty through large data services, e.g. as COPERNICUS. Quantitative estimates can reflect Avoided losses or/and damages, Value of Information, indicators of knowledge spill-overs and potential increasing returns from COPERNICUS services and data in various fields (i.e. industries, agriculture, biodiversity protection, air quality, emergency management, crisis prevention, preparedness and response, tourism, etc.), which justify the creation and growth of scientific and business projects using data and information access services. At the same time, continuous updating for new and improved datasets poses a challenge for the modelling and decision support tools provided the requirements for advanced data processing, assimilation and strategic decision support analysis.

An integrated environmental-economic model for robust pollution control under uncertainty

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Nitrogen and phosphorus are key elements in agricultural practices for crops growth. At the same time, they are dangerous potential polluters of soil, land, and waters, contributing to poor surface and ground waters quality. In Europe, the Water Framework Directive and the Nitrates Directive include direct and indirect measures to control the use of nutrients in agriculture and to reduce nutrients leaching from agricultural land to surface and ground waters. In our talk, we present an overview and compare recent studies on developing and applying methodologies for nutrients accounting and best management practices (BMPs) to minimize agricultural nutrient losses to the environment in the EU and North America. Although a wide variety of methods exist, research predominantly concentrates on deterministic frameworks with an implicit assumption that the ecosystem is deterministic and the social planner/farmer faces no uncertainties. While convenient, these assumptions may lead to overly simplistic representations of reality, given that ecosystems are inherently stochastic. Uncertainty may be particularly important to be captured in coupled human-natural systems. There is legitimate concern that deterministic models calibrated with average parameter values may lead to suboptimal policy recommendations. We therefore verify the hypothesis if ignoring the stochastic nature of nutrient emissions leads to loose guidelines for fertilizer application and water and soil pollution control measures. In the talk, we focus on phosphorus accounting and BMPs modelling. The study examines how weather uncertainties affect optimal choices of BMPs over adaptation by building on an integrated economic-agricultural-hydrological model of BMPs and combine it with the recent development in decision making under uncertainty relying on methods of nonsmooth stochastic optimization. The environmental security constraints are introduced in the form of quantile-based probabilistic constraints, assigning a realistic reliability level to meet the specified environmental targets. This stochastic optimization framework for phosphorus management is able to provide recommendations regarding robust BMPs under uncertain climate change and stochastic weather events. The model has been applied in several EU projects, and the results have been negotiated with representatives from EC DG Agri, Environment, Clima, emphasizing the need for risk-adjusted pollution/nutrients accounting and BMPs recommendations.

Comparing the policy guidelines with a deterministic model using expected precipitation and emission levels, we find that incorporating stochasticity results in qualitatively different policy recommendations for the BMP adoption path. The results from practical case studies caution that neglecting stochasticity can result in insufficient mitigation strategies. We quantify as well how much the stochastic policy guidelines outperform the deterministic solution in terms of profit, and show that significant gains can be achieved from using robust solutions. More generally, this work shows that the adoption of stochastic optimization methods in environmental economics provides robust policy prescriptions under uncertainty and risks, and that deterministic models based on traditional scenario analysis cannot provide adequate decisions in the presence of uncertainty. In addition, the proposed method allows decision makers to select an acceptable risk level along with the corresponding cost of violating the environmental constraint. By monetizing risk levels, the framework provides a versatile tool for decision support with powerful policy implications. The framework demonstrates urgent need to account for uncertainties and risks while deciding on environmental pollution control policies. We illustrate the framework with two case studies in the UK and US.

Policy impact on biofuel or electricity production from biomass in Europe

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As a low-carbon energy resource and a carbon management mechanism, biomass is expected to play essential role in the transformation of European energy sector under stringent climate change mitigation accords. In the last two decades, biomass has attracted a growing interest for developing conversion technologies that generate bioenergy and biofuels using different types of non-food feedstock like agricultural and forest residues. The efficient utilization of modern bioenergy technologies will be of high importance for the future development of the European energy supply system, especially in balancing out fluctuations in energy generation from other renewable sources like wind and solar.

The present study investigates the long-term potential of non-food and non-industrial biomass feedstock for energy purpose in Europe and a strategic model-based techno-economic feasibility of converting the identified feedstock to energy products. A geographically- explicit techno-economic model, BeWhere has been developed at the European scale at a 40km grid size, to assess the potential of bioenergy and biofuel from non-food feedstock. The model is a mixed integer linear program, it is based on the minimization of cost and emissions of the full supply chain from feedstock collection to the final energy product distribution to the consumers. The model identifies the optimal bioenergy production plants in terms of spatial location, technology and capacity. The feedstocks of interests are woody biomass (consisting of eight types from conifers and non-conifers) and five different crop residuals. For each type of feedstock, one or multiple technologies can be applied for either heat, electricity or biofuel production.

The model is run for different policy tools such as carbon cost, biofuel production incentives, or subsidies to name a few. The optimal mix of technologies and biomass needed are optimized to reach a production cost competitive against the actual reference system which is fossil fuel based. At the same time, the impact of the trades on the European bioenergy potential is investigated in three additional scenarios: no trades, free trades and trades not higher than the domestic biomass consumption.

The results show that a maximal amount of emissions substituted (about 60 MtCO2 a year) would be reached at high carbon price. Allowing trades of feedstock between the European countries would decrease the emissions by half compared to a scenario for which trades are not allowed. The trades allow the countries with a high share of fossil fuel in their energy mix to increase their bioenergy production and at the same time decrease their emissions. This means that the European countries should collaborate to decrease the emissions of the countries which are still heavily depending on fossil fuel.

Futher reading

BeWhere: www.iiasa.ac.at/bewhere

Robust food-energy-water-environmental security management: linking distributed sectorial and regional models

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Increasing global-local, as well as sectorial interdependencies may significantly affect business-as-usual operations, even under small local disturbances. This calls for the development of adequate integrated models enabling truly integrative decision support for optimal solutions across sectors and regions. Detailed sectorial and regional models have traditionally been used to anticipate and plan desirable developments of respective sectors and regions. However, solutions that are optimal for a sub-system may turn out to be infeasible for the entire system. In this talk, we discuss a new modelling approach enabling the linkage of detailed models of subsystems under joint resource constraints. The models act as 'agents' that communicate with each other via a 'central hub' (a regulator or a planner). In this way, they continue to be separate models, and different modeling teams do not need to exchange full information about their models — instead, they only need to harmonize the inputs and outputs that are part of the joint resource constraints. In other words, in this approach the agents operate under asymmetric information. The applicability of the developed approach is demonstrated for a case study that focuses on the food-energy-water-environmental nexus of agriculture and the coal industry that are competing for limited water and land resources.

The approach for linking models is based on an iterative process of non-smooth stochastic optimization converging to the socially optimal solution. It does not require models to exchange full information about their specifications. The 'resource quotas' for each sector/region and each resource are recalculated by sectors/regions independently by shifting their current approximation in the direction defined by the corresponding sectorial/regional dual variables from the primal sectorial optimization problem. In this way, we avoid a 'hard linking' of the models in a single code. This also preserves the original models in their initial state for other possible linkages. Using detailed sectorial/regional models instead of their aggregated simplified versions also allows for taking into account critically important local details, which are usually hidden within aggregate data.

The algorithm is being developed at IIASA in partnership with Institutes from IIASA National Member Organizations for linking national sectorial models with global models (such as e.g. IIASA MESSAGE and GLOBIOM models). Therefore, linkage is considered as not only linking regional and/or sectorial, models but also, more generally, linking models may refer to different local-global scales. The proposed computational algorithm is based on generalized gradient methods invented for the optimization of non-smooth systems, which may be subject to shocks and discontinuities. These methods enable to link stochastic models with known marginal distributions of sectorial uncertainties, into cross-sectorial integrated models with joint distributions of collective systemic risks induced by sectorial uncertainties and decisions maximizing a stochastic version of the function.

Parallel sessions 3

Modelling value chains in global trade

Room 0.C

26 November

16:00 – 17:30

Challenges of conducting policy impact analysis using PE models: the case of Brexit

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The objective of this research is to analyze the export potential of selected agricultural commodities in the event of a Brexit and highlight the challenges faced using PE models for this analysis. Trade elasticities play a central role in estimating the effects of trade agreements as well as estimating the impacts of specific policy changes. Accurate and up-to-date trade elasticities are important to trade policy makers that rely on these key parameters for assessing the trade impact of a policy shock. Currently the trade modeling community relies on trade elasticities that are outdated, heavily aggregated, or estimated through poorly specified econometric approaches. The elasticities used by most trade modelers were estimated from time series data that ended in the late 1980's, 1990's or early 2000's. Also, many of the General Equilibrium (GE) and Partial Equilibrium (PE) models are predicated on a set of import demand, export supply, and substitution elasticities that are often incomplete and outdated. This would suggest that these elasticities would not adequately reflect the structural changes that have affected the global agricultural production and food consumption landscape during the past decade.

We develop the Foreign Agricultural Service Trade Analysis Model (FASTAM) which is based on the Food and Drug Administration's Trade Impact Model, which was derived from the Global Simulation Model (GSIM). The GSIM is a partial equilibrium model developed by Francois and Hall (2003) that is scalable and allows for the simultaneous assessment of trade policy changes at the industry level and on a global or national level. The core assumptions underlie the FAS Trade Model are perfect competition where competition from current rivals or the threat of entry by new rivals helps reduce prices to the marginal cost of production and the Armington assumption of product differentiation where consumers view foreign varieties of a product as imperfect substitutes for the local variety of that product. This assumption identifies the existence of two-way trade (i.e., bilateral exports and imports of goods in the same products category) as the result of consumer tastes.

The model is parametarized with import demand elasticities obtained from Ghodsi et al. (2016), which are available by product and country. A semiflexible trans log GDP function approach is used to derive import demand elasticities and the UN Comtrade system–based data on import values and quantities across 167 countries and 5,124 products at the six-digit HS level for the period 1996 through 2014. Export supply elasticities were obtained from different sources because no one source covers the elasticity estimates for all the products of interest. Elasticities of substitutions between domestic and imported goods is assumed to be equal and constant across products and countries (constant elasticity of substitution). These elasticities were obtained from different sources because no single source covers the elasticity estimates for all the products of interest to the Foreign Agricultural Service. These sources include Reinhart and Roland-Holst (1992), Gallaway et al. (2003), and the Global Trade Analysis Project database (Narayanan and Walmsley, 2008). However, there were many product–country pairs for which an elasticity estimate was not available.

We highlight a series of challenges in the development of a PE model, including parameterization and data issues. We explore approaches to improve the data and parameters, including filling product–country pairs for which an elasticity estimate was not available. We analyze the potential impact of policy changes of Brexit, namely the potential changes in tariffs on U.S. exports under a range of scenarios and identify opportunities that could exist for expanding U.S exports of selected agricultural commodities to the United Kingdom.

Shooting oneself in the foot? Trade war and global value chains

Bellora C., Fontagné L., PSE, University Paris 1 and CEPII

Since early 2018, the United States' administration has taken several measures to limit US imports, in particular from China. This has fuelled retaliation and has escalated in high trade tensions at the global level. In addition to the measures already implemented, the belligerents currently contemplate two alternative routes: either open new fronts (particularly in the automotive industry, targeted primarily against the European Union and in particular Germany, but also to Japan), or have a rest to avoid further damages.

For the most part, measures currently in force increase trade barriers on intermediate goods, whereas historically goods for final consumption were the most protected. We show that the current trade policy will be detrimental not only to the targeted countries, but also to American value added. Two mechanisms operate, beyond the direct impact of retaliation. First, US imports subject to higher tariffs inevitably contain US value added (e.g. US components assembled abroad), notwithstanding the fine-tuning of the lists of targeted products. Second, US exports will also suffer a loss of competitiveness, as production costs increase in industries that use taxed imported goods as inputs.

We address the trade and welfare effects of the current trade tensions by tracing the impact of protection along the value chains, in general equilibrium. We take on board all measures enforced at the time of writing (including voluntary export restrictions, retaliations and safeguards), based on the official lists of additional tariffs, as well as the current trade agenda. Two measures are on the horizon, namely: (i) the US investigation on the automobile industry likely to trigger US trade sanctions; (ii) the European decision of 15 April 2019 to launch negotiations with the US on a trade agreement restricted to industrial goods (but excluding the automotive sector).

The new tariffs have indeed a direct impact on the targeted products and countries, but global value chains, along with general equilibrium effects, trigger consequences also on third sectors and countries. These are the indirect effects possibly contributing to imposing countries doing themselves a disservice. Indeed, global value chain linkages modify countries' incentives to impose import protection, as the optimal tariff depends on the nationality of value-added content embedded in domestic and imported final goods. Tariffs should be decreasing in the domestic content of foreign-produced final goods and in the imported content of domestic production of final goods. However, even before the recent escalation, temporary trade barriers have moved away from final goods towards intermediate goods, starting from 2010, following a pattern contrary to the ubiquitous tariff escalation.

CGE modelling in imperfect competition is a good candidate to address the effects of this trade war, in particular when the dynamic impacts of the trade war have to be characterized. Sectors adjust their intermediate consumption basket to tariff-induced price changes, labour force and capital accumulate, and the overall setting can be linked to a macroeconomic baseline. One drawback of CGE modelling recently fixed is the way GVCs were modelled. We rely here on MIRAGE-e2, a version that integrates and importantly differentiates demand of goods according to their use, for final or intermediate consumption, thus properly representing GVCs. As for tariff increases, we rely on the official lists, but our scenarios differ from the recent literature (i) in the way we aggregate these information and (ii) in how we take into account voluntary export restrictions. Tariffs are aggregated by a simple mean to move from the 8 to the 6 digit levels and then by a reference group weighted mean to reach the level used in our simulations. As far as Voluntary Export Restraints (VERs) are concerned, we assume that the negotiated quantities are exported each year; the target in volume is reached using an export tax, endogenously computed. This solution is appealing in that it generates a rent that accrues to the exporter (contrary to a tariff).

According to our estimates, the measures already implemented would cause significant value-added losses to China (USD 91 billion in the long run), but also to the United States (62 billion), due to the intertwining of global value chains. Because of vertical linkages along the value chains, 20 out of our 25 sectors decrease their value added in the US, suggesting that with this tariff war the US are shooting themselves in the foot. China and the United States could experience GDP losses by 0.4% and 0.3% respectively. As in any war, imposing losses on an enemy comes at a high cost.

If the tariff war were to escalate, German industry would pay a heavy toll. The opposite path, a lull through an agreement on industrial goods between the United States and the European Union, would avoid undesirable outcomes, but would bring little gain *per se* to the parties.

MAGNET — a team-based modular CGE approach for coherent cross-cutting policy assessments

Kuiper M., van Meijl H., Tabeau A., Wageningen Economic Research, Wageningen University & Research

The policy landscape is becoming increasingly complex with interrelated global challenges stretching across domains previously handled in relative isolation. Prime examples are the sustainable development goals (SDGs) adopted in 2015 with ambitious goals for both developing and developed countries to end poverty, improve health and education, reduce inequality and spur economic growth while tackling climate change and preserve natural resources both on land in in the oceans by 2030 (United Nations 2015). Alongside the SDGs many countries including the European Union member states, committed to halt climate change as part of the 2016 Paris agreement (UNFCCC 2016) which will have widespread repercussions for the way in which the world economy operates.

SDGs and Paris commitments require policymakers to look at impacts beyond their own domain and decades ahead. With feedback loops abound, impacts of interventions become theoretically ambiguous requiring ex-ante integrated modelling tools to explore expected impacts of policy interventions, trade-offs and synergies across multiple domains. This calls upon researchers to connect previously separate strands of research and has resulted in a burgeoning integrated assessment literature (van Vuuren et al, 2015, Stehfest et al. 2014).

This paper describes how these challenges are met by MAGNET, a global economic model designed to combine generally separate strands of research in a flexible and coherent manner. MAGNET (Modular Applied GeNeral Equilibrium Tool) is unique in covering food security, sustainability and inclusiveness in a single economy-wide framework. In contrast to partial agri-food models MAGNET is a computable general equilibrium (CGE) model covering income feedback loops and the full (bio)economy thus capturing feedback between primary and industrial sectors (Banse et al. 2011, Van Meijl et al. 2018) beyond the grasp of partial models. This wider coverage comes at the costs of technological detail, which is addressed by allowing a link to partial models like IMAGE and GLOBIOM, to exploit each other's comparative advantage (van Meijl et al. 2006, Doelman et al. 2018, Frank et al. 2019). MAGNET can also be combined with technical models like TIMER or MARKAL (Wicke et al. 2015, van Meijl et al. 2018), capturing adjustments in cost structures as well as smoothing changes in technology due to economic feedback loops not accounted for in these technology focussed models. Compared to other CGE models MAGNET has more bio-economy detail absorbed through the cooperation with non-economic models and combines all its extensions into a single model instead of parallel developments by different teams of researchers. It also includes climate specific modules as GHG emissions and stock, potential and actual temperature change and CO2 taxes. MAGNET has been designed and developed as a team-based model connecting specialist expertise from different strands of research in a single model platform. To avoid excessive complexity in specific applications it has been designed in a modular way allowing researchers to combine model extensions tailored to the question at hand. Hence there is no single 'MAGNET model' but the model's scope can easily be adjusted both in terms of model structure and data preparation.

The core of the paper describes MAGNET is it now stands. We go beyond a description of the available modules in also describing the technical implementation of the modularity both in setting up the model code and additional purpose build software to support modular development in the GEMPACK software in which MAGNET is coded. Similar tools are available for GAMS-based models, hence lessons learned from building MAGNET are relevant for the wider modelling community. We also shortly touch upon the team-based development of MAGNET which poses its own opportunities and challenges beyond the technicalities of such a model platform, and is critical for the long term success of such an endeavour.

MAGNET has been successfully applied to support policymakers across different domains. Examples are in the field of trade policies, GMOs, and technical change (Meijl and Tongeren 1998, 1999, Huang et al 2004, Francois et al. 2005, Smeets-Kriskova et al. 2017a, 2017b), agricultural and land use policies (Meijl et al. 2006, Nowicki et al. 2009, Banse et al. 2008), biobased economy (Banse et al. 2008, Meijl et al. 2018a), food security (Kuiper et al. (fortcoming), Shutes et al. fortcoming), climate (Nelson et al. 2013, Meijl et al. 2018b, Hasegawa et al. 2018, Frank et al. 2019). These past applications show how MAGNET through its modular team-based development, addresses the need for a flexible but coherent assessment of policies across multiple and sometimes inherently conflicting objectives of SDGs and the Paris agreement.

We conclude by summarizing lessons learned from last 10 years of MAGNET development relevant for both the modelling and policymaker communities.

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Environmentally conscious transportation and logistics modelling for agri-food supply chains

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Agriculture and fisheries are areas of deep policy integration at the EU level, organised through the Common Agricultural Policy (CAP) and Common Fisheries Policy (CFP) respectively. To implement and monitor the effects of the CAP and CFP considerable data collection occurs across Member States at the level of primary production. This allows for modelling the economic impacts of existing and potential future policy on, for example, agricultural / fisheries output, incomes, land use / fish stocks through partial and general equilibrium models (European Commission, 2016a; M'Barek et al., 2017).

However, the existing infrastructure for agri-food policy modelling suffers from two main weaknesses. First, modelling focuses on primary production, rather than the whole supply chain. Hence, existing models typically do not capture the linkages between primary producers and downstream actors despite the nature of these relationships shaping profoundly outcomes at the primary level such as farm and fisher incomes (Falkowski et al., 2017). Consequently, evaluating the impact of new EU policy initiatives that take a supply chain perspective (e.g. Directive 2019/633 on Unfair Trading Practices in the agricultural and food supply chain) faces significant challenges within the existing modelling framework. The second main weakness relates to the lack of/limited interactions between policies across sectors as for example, between agriculture, food and transport. The current policy-modelling framework is tailored toward a sectoral approach (e.g., the Farm Accountancy Data Network capturing outcomes of the CAP at the farm level). Yet, the achievement of EU policy objectives increasingly requires an integrated approach (European Commission, 2016b). For instance, the transport sector accounts for approximately one quarter of overall greenhouse gas (GHG) emissions in the EU (European Parliament, 2019) and the Joint Research Centre (2006) estimates that 29% of all consumption derived GHG emissions are food related. Key indicators such as distance between supply chain actors, export capacity, fuel efficiency and green tax incentives are known to influence food prices and output (Soysal et al., 2014). However, the integration of policies in modelling between these two sectors is limited (Petrov et al., 2017).

In response to these gaps, this paper aims to provide a robust model of transportation and logistics for agri-food supply chains for policy support. It undertakes this through two illustrative cases: salmon in Norway and processed tomatoes in Italy, conducted as part of the EU H2020 VALUMICS project. For both cases, we developed multi-echelon, multi-period, supply chain models, informed by the literature (Govindan et al., 2015). The research work carried out in the paper pays attention to experiences and problems encountered in developing the models, data issues, results and sensitivity analysis. Model development, validation and policy recommendation occurred in four stages: (i) mapping supply chain linkages and product flows, (ii) designing the mathematical model, (iii) data collection for parameters of the model and (iv) model validation and deriving policy recommendation. We concentrate on providing key insights pertaining to each stages associated with model development, validation and policy recommendations via stakeholders' consultation (Govindan, 2018).

For the first stage, it was necessary to map the supply chain linkages and understand the nature of flows amongst stakeholders. This could not be accomplished solely from considering the existing literature and available secondary data. Hence, expert interviews were conducted for each case study to refine the conceptual maps. Without adequate conceptualisation of the supply chain, it was not possible to build appropriate mathematical models. Figures 1 and 2 present the supply chain networks for Norwegian salmon and Italian processed tomatoes respectively.

In the second stage, mathematical models for salmon and processed tomatoes were developed based on the framework presented in Figure 3. The objective function within each mathematical model aims to minimize total cost, comprising of the costs associated with transportation, fuel consumption, inventory holding, processing and residuals/waste. Restrictions associated with carbon emission and wastage are considered for addressing the sustainability aspects. Constraints related to supply, processing capacity, storage capacity, demand, carbon emissions, inventory balancing, transportation capacity, and different modes of transportation between different types of plants and facilities are taken into consideration.

In the third stage, the primary data collection is performed pertaining to various input parameters provided in the framework of the mathematical model, supplied by the industry stakeholders. Information related to the cost components, capacity restrictions, carbon emission coefficients, and fuel consumption rates considering various scenarios associated with choice of transportation mode and the supply and demand variability in different time periods.

The fourth stage aims to resolve the models and obtain necessary managerial recommendations for various scenarios. The models are valuable for policy makers in terms of understanding the costs and emissions associated with different food supply chains, as well as the effects of particular policy interventions and market developments (e.g. variation in demand, fuel costs, emission and waste constraints). They can aid supply chain managers to make decisions regarding the amount of inventory to be kept in different time periods. The models are developed for a planning horizon consisting of discrete time periods, aiding the possibility of studying demand and supply uncertainty and its consequences in supply chain decision making. Hence, they help decision makers to identify the changes in a supply chain network when different transportation routes are adopted (for example whether maritime routes can be adopted or not in place of road/rail transportation, to address environmental concerns related to fuel consumption and carbon emissions). The models generate valuable insights for supply chain managers,

Figure 1: Conceptual framework for the Norwegian Salmon Supply Chain Network

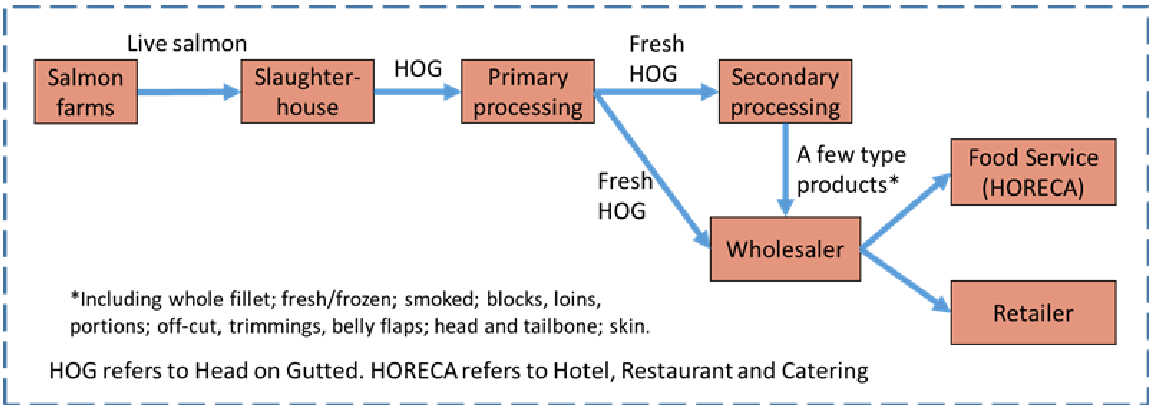


Figure 2: Conceptual framework for the Italian Processed Tomato Supply Chain Network

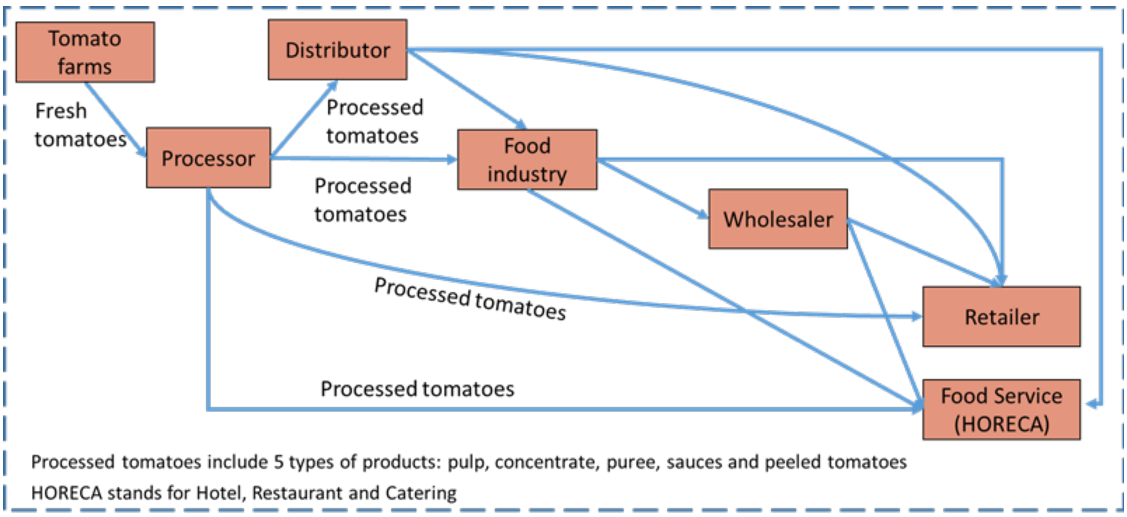
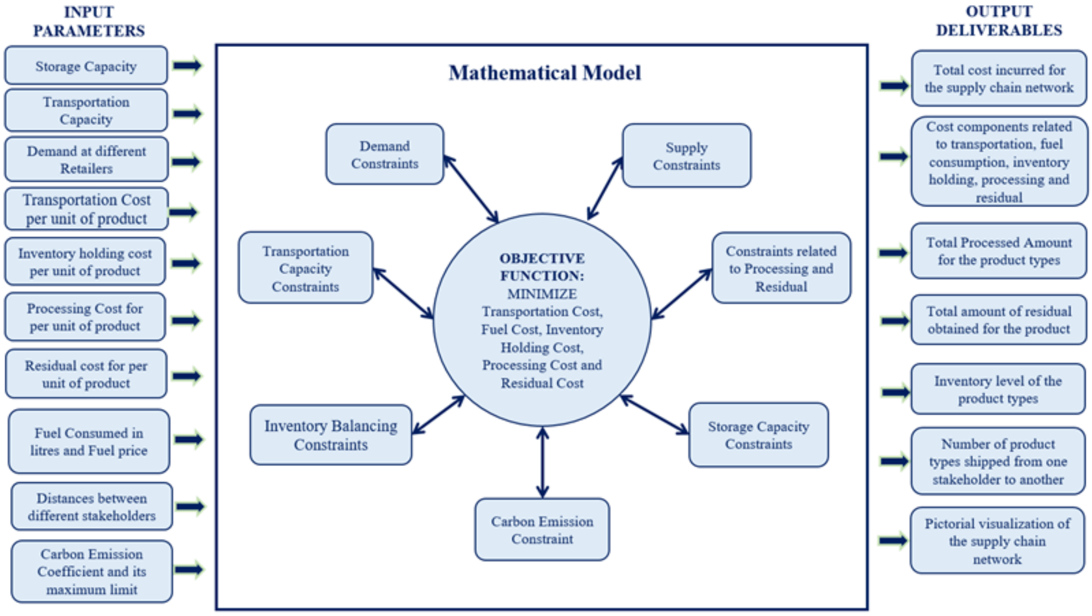


Figure 3: Framework for the model for both products



understanding the effects of different scenarios associated with demand and supply uncertainty and the adoption of different transportation routes. Based on the sensitivity analysis, policy implications can be drawn.

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Modelling fairness in FVCs: developing quantitative indicators

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Introduction

Unfair trading practices (UTP) within food supply chains are of increasing concern to European Union (EU) and member states' policy makers (DG IPOL, 2015). Findings indicate that their negative impact on SMEs in the EU food sector is affecting the competitiveness of the industry as a whole (Wijnands et al., 2007). Although UTPs can arise in any market or sector of an economy, they have the potential to be especially problematic in food supply chains, as agricultural producers may be placed under undue pressure and have limited bargaining power in negotiations with larger purchasers, such as supermarkets or retailers, given the lack of alternative buyers (Duffy et al., 2003, Falkowski et al., 2017). As a counter measure, the recent EU Directive (2019/633) on UTPs aims at protecting weaker 'suppliers', primarily farmers, including their organisations (e.g. cooperatives) against their buyers, as well as suppliers of agri-food products which are further downstream (European Parliament, 2019). Due to the topicality and policy relevance of fairness in FVCs there is value in exploring its dynamics through simulation modeling.

Aims and objectives

This research forms a part of VALUMICS, an ongoing Horizon 2020 EU funded project on food value chains (FVCs). The overall objective of the project is to develop a comprehensive suite of tools that will enable decision makers to evaluate the impact of strategic and operational policies on the resilience, integrity and sustainability of European FVCs. In particular, the current research concerns the development of a simulation model focused on fairness in FVCs and the objective is to develop quantitative indicators of fairness that are operational in the model. The degree of fairness in inter-firm relations is a perception and therefore it is necessary to define quantifiable indicators to be used for the simulation model.

Modelling fairness

Simulation modeling is well suited for the development and testing of policy interventions. Food systems have been described as complex adaptive systems (CAS) as they are characterised by a large number of interactions and interdependencies which leads to nonlinear, emergent system behaviour that is not easily controlled. Individual agents impact the system with actions resulting from their localised decision-making and in turn they are constrained by the system structure. In a sense, the system is self-organising from the viewpoint of the individual agent (Choi et al., 2001; Surana et al., 2005) and its structure and extended operation are to a large extent invisible to them. The same applies to policy-makers, for whom a lack of a whole-chain overview makes it difficult to predict the effects of policy implementations beforehand (Stave & Kopainsky, 2015). In addition to their structural complexity, food systems are heavily influenced by social and environmental factors.

Agent-based simulation modeling (ABM) has been successfully used to model CASs. Such models are typically built from the bottom up by identifying agents in the system and defining their behaviours, including how they interact with other agents and their environment. The behaviour of the system as a whole emerges out of multiple concurrent individual behaviours. In VALUMICS, the aim is to use the ABM to identify the level of fairness within the system, which emerges via concurrent execution of decision rules on behalf of multiple independent agents in the FVC.

Method

As fairness is an intangible concept it is not a straightforward task to define it in simulation model operational terms. In order to do so we draw on fairness theory and related literature on governance and market power in FVCs (Busch & Spiller, 2016; Gereffi et al., 2005; Carbone, 2017). To further substantiate the establishment of quantitative indicators two dissimilar European FVCs are explored, an aquaculture chain and an agricultural chain. As food supply systems these two chains have many things in common. The agents in the chains are similar (i.e. primary producers, producers, retailers and consumers) and the perishability of the final product affects the workings of both chains. While FVC are similar in many aspects, aquaculture and agricultural chains vary with respect to governance, power structure, contractual agreements and pricing practices. The governance structure of the FVC is explored in the emerging literature from the VALUMICS project (Barling and Gresham, 2019). Furthermore, fairness perceptions of agents in the chains will be studied by surveying actors across the FVCs and asking for perceptions on fair compared to actual gross margins, as well as analysing responses to a series of statements on the distributive and procedural components of UTPs according to a conceptual model on fairness in sustainable supply chains (IIED/Oxfam, 2012).

Preliminary results

The result of the present study will be quantitative indicators of fairness that can be used in the VALUMICS simulation model to analyse and test policy interventions related to fairness in FVCs. When examining quantitative metrics for distributive fairness we take into account the importance of price, for agents in the FVC in their effort to maximize their profit or utility. Furthermore, the influence of market power with respect to creating opportunities for misuse of power in the form of UTPs, is considered to be of relevance. Price movements threatening the margin of firms being able to exert market power are transmitted faster than price movements that improve it (Falkowski et al., 2017). Given this, the VALUMICS project will integrate quantitative economic indicators into its ABM to gain enhanced understanding of distributive fairness in the aquaculture and agricultural FVCs. First, the gross profit margin obtained by the various actors across the FVCs will be assessed. Second, the degree of market power will be investigated by using the Lerner Index, which provides an estimate of market power in an industry, measuring the price-cost margin through the difference between the output price of a firm and the marginal cost divided by the output price (Elzinga & Mills, 2011). The aim will not be to determine an absolute measure of fairness using these indicators, but rather to ascertain transitions towards fairer outcomes. This approach is in keeping with the European Parliament's depiction, which, rather than providing a strict value measure of UTPs, emphasises the presence of gross deviations away from good commercial conduct.

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Poster session 1

26 November

A global sensitivity analysis of smart grids project cost benefits analysis with correlated inputs

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In this work, Uncertainty Analysis (UA) and Global Sensitivity Analysis (GSA) are carried out on a Smart Grid project's benefits and costs in order to identify main input sources of uncertainty. This approach yields significant improvements in terms of accuracy in the estimation of costs and benefits of the selected project, namely the Net Product Value (NPV).

The thorough account of Smart grid projects' costs and benefits is in fact characterized by significant uncertainty: each unique, capital intensive project tests new technologies and site-specific solutions for which a clear assessment cannot rely on the evidence from other projects. In this study, for the first time the Joint Research Centre (JRC) applied to the Cost Benefit Analysis of a real Smart Grid project a Global Sensitivity Analysis taking into account correlation hypothesis among variables.

The analysis is performed around two scenarios: one where the Smart Grid solutions are implemented only in the pilot project area of 'Malagrotta', and another one where they are extended to the whole distribution network of the city of Rome, Italy.

Data for both scenarios are gathered from the Italian Distribution System Operator, ACEA - one of Italy's biggest one, and a simple Cost Benefit Analysis has been already performed in Vitiello et al., A Smart Grid for the city of Rome - A Cost Benefit Analysis. 2015. doi:10.2790/50100.

Based on this latter report, this new piece of research aim at showing that the standard practice in CBA of the One-at-a-time (single-factor) sensitivity analysis (SA) might be significantly improved when coupled with Uncertainty Analysis and Global Sensitivity Analysis, that allow capturing the possible interactions among the different parameters used. In addition, the current work also investigates possible dependence relationships among inputs of the CBA.

The following eight input factors were taken into account as causes of output uncertainty:

1. Social Discount Rate (SDR)
2. Yearly average rate of decrease of benefits from software infrastructure
3. Yearly average rate of decrease of benefits from physical infrastructure
4. Yearly average rate of electricity demand increase
5. Value of 1 ton of CO_2-equivalent average price on the ETS market
6. Emission factor

In the Rome's case other two inputs were added to the study, that is:

1. Yearly increase in CAPEX costs
2. Yearly increase in OPEX costs

The first step of the analysis was the output variability quantification (NPV). This variability derives from the input uncertainty propagated through the model. Therefore, the ranges of variability of each input and their probability distribution functions must be estimated.

These estimations might depend on several elements which should be identified by the experts of each Smart Grid project on the basis of the specific problem they are considered. This means that different UA/SAs might be necessary when the same model is applied if the context of the plan changed.

In our study, two different Monte Carlo simulations of the CBA models have been conducted, one for the Malagrotta project referring to Malagrotta NPV, and one for the Rome's project to analyse its distribution network NPV.

Consequently, two Monte Carlo samples of the input of size Nxd (N=256, d=6 for Malagrotta and d=8 in the Rome's case) have been created. These two samples were represented by matrices of random input values generated from their probability density functions. Each matrix row was a set of the six values (eight inputs for Rome) used to run the CBA model. Also the dependences among significant variables have been shaped, as indicated by the experts.

These correlations among the significant inputs were then taken into account when first-order indices were computed. With this aim, we made use of the regression technique proposed in Mara and Tarantola (2012).

The two projects have undergone the same sensitivity analysis steps and very similar results were obtained. The Malagrotta and Rome's SDR indices show the highest values (0.98 and 0.96 respectively). This proves once again the high relevance, in terms of uncertainty impact, of this input (see JRC report).

The electricity demand increase index remains constant with a percentage of about 0.20. Eventually for the Rome's network, the CAPEX and OPEX indices are significant with an index value equal to 0.42 and 0.28 respectively.

Note that the sum of the individual main Sobol' indices is higher than one. Under the theoretical assumption of independent input factors, this sum cannot exceed the unity. We therefore must conclude that some correlation exists among some inputs.

Significant improvements over standard sensitivity analysis were obtained by this GSA of CBAs for Smart Grids projects. It allowed knowing more comprehensively the uncertainty affecting the results (NPV), and reliably evaluating the contribution of each parameter in the determination of a positive Net Present Value for the project.

The authors strongly recommend the use of GSA, as a standard tool, to carry out Smart Grids Costs Benefits Analyses. Given the wide diffusion of CBA as a tool in impact/risk assessment, in many fields, this work is a very promising achievement.

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A participatory process to design regional policy for rural development: the case of the Veneto Region

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Recently, the European Union is witnessing a crucial moment that coincides with the conclusion of the multi-annual policy framework programmes 2014–2020 and the necessity to look at the future. Accordingly, the European Agricultural Policy (CAP)'s agenda is undergoing a reform process that drives the necessity to efficiently analyse and design the new policy through models that prefigure the most appropriate strategies to achieve future goals. Indeed, agriculture makes extensive use of models as other relevant policy areas. The CAP takes action with rural development measures with national and regional programmes to address the specific needs and challenges facing rural areas: to this purpose, the drafting of future rural development strategies (II pillar of the CAP) is experiencing a lot of ferment in Italy especially at regional level. In this regard, after a long process of exchange and debate among the stakeholders (through structured interviews) the Veneto Region, which is actually the first in Italy to draft a strategic document so far, has just concluded a concrete experience of operational joint collaboration between 31 experts (with the direct involvement of both scientists and policy makers) and a public partnership with a regional conference, thus tracing a model that could be easily replicated both regionally and nationally for policy support and implementation.

This abstract describes the participatory process through which, by means of a combination of qualitative and quantitative methods, the Veneto regional strategy for rural development (agriculture, forests, rural development) until 2030 has just been defined, in the context of the perspectives and objectives (e.g. the CAP's 9 key objectives + 1 transversal objective) and rules (e.g. the CAP's New Delivery Model for a more results-oriented policy) outlined at the community and national level for the CAP post-2020 as well as in reference to the regional government program.

In particular, starting from the SWOT (strengths, weaknesses, opportunities, and threats) analysis and the 32 needs defined at regional level, 43 strategic options have been evaluated through a multi-criteria analysis by 31 experts, in terms of efficacy (from low to high) to achieve the EU objectives, and selected by more than 100 public stakeholders involved in a structured online survey. Based on these, policy makers will design their regional priorities, aligned on the EU objectives, and the most appropriate measures to support farmers at regional level, with a view to achieve a more performance-based governance system while respecting the overall sustainability goals at European level.

Defining the applicability of animal-free approaches for skin allergy testing of chemicals

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In order to assure the safety of the European population, chemicals produced or marketed in the European Union in quantities of one tonne or more per annum must be assessed for their potential to cause adverse effects (EC, 2006). One of the endpoints that must be assessed is skin sensitisation, which is the first step of allergic contact dermatitis (ACD) in humans. ACD is the clinical manifestation of a changed responsiveness of the adaptive immune system following repeated exposure to a sensitising substance.

The assessment of skin sensitisation has traditionally been based on the use of animals, being the less invasive test the local lymph node assay (LLNA), which, however, still implies the sacrifice of the animals. The international scenario changed in 2013 when the Cosmetics Regulation (EC, 2009) entered into force and banned the use of animal testing for cosmetics in Europe. Moreover, since 2016 the REACH regulation demands that testing on vertebrate animals should be considered only as last resort (EC 2016).

Mechanistically based in vitro methods that capture the key (biological) events (KE) that are considered necessary for the acquisition of skin sensitisation (OECD, 2012a,b) represent one of the most prominent alternatives to animal testing. In fact, three-animal free methods have been validated by the European Union Reference Laboratory for Alternatives to Animal Testing (EURL ECVAM). These methods are: the direct peptide reactivity assay (DPRA) (EURL ECVAM, 2013; Gerberick et al., 2004), KeratinoSensTM (Emter et al.,2010; EURL ECVAM, 2014; Natsch and Emter, 2008), and the human Cell-Line Activation Test (h-CLAT) (Ashikaga et al., 2006; EURL ECVAM,2015; Sakaguchi et al., 2006). Despite these methods being predictive of LLNA responses with an accuracy of about 80%, the data generated are not considered equivalent to animal test data for regulatory purposes.

Instead, the most promising alternative to animal testing seems to be the use of these data in combination with other relevant information (e.g. physicochemical properties, in silico, in chemico, in vitro data) in the context of Integrated Approaches to Testing and Assessment and Defined

Approaches (DA). DAs consist of a fixed data interpretation procedure (DIP) used to interpret data generated with a defined set of information sources, that can either be used alone or together with other information sources, to satisfy a specific regulatory need. Several DAs for skin sensitisation have been proposed to combine KE data. These include the use of machine learning algorithms (e.g. classification trees, Bayesian networks, and neural networks) (Asturiol et al. 2016, Hirota et al. 2015, and Jaworska et al. 2013).

The use of these new methodologies based on the integration of data represents a regulatory challenge because so far only individual testing methods have been translated into OECD test guidelines. Once adopted, these OECD test guidelines fall under the mutual acceptance of data (MAD) meaning the data generated with one of these methods in any of the OECD member country with one of these methods should be automatically accepted in the other OECD countries.

The main difficulties correspond to the fact that DAs have not undergone any formal validation to characterise their reproducibility, transparency, relevance, and accountability; and do not have dedicated OECD test guidelines. In addition, computational methods in general and machine learning algorithms in particular have traditionally been treated differently from testing methods and have never been included in a test guideline.

The JRC is playing a key role in this process to develop, promote and validate new methods. In particular, the JRC is leading the international efforts to characterise the DAs in the light of the elements above and determine the information that needs to be reported so that DAs and computational methods are considered at the OECD level under the MAD and therefore transparent, relevant, accountable, auditable, and trustable methods.

In order to improve the transparency and trustworthiness of these methods, the JRC has proposed the formal definition of the chemical space and applicability domain of DAs, i.e. the interpolation space in which the method is expected to provide reliable results. In addition, standard reporting is needed for such methods to be used under MAD and the JRC has developed standards to describe and report the applicability domain of DAs in a simple and straightforward manner that can be applied to the different DAs available independently of their complexity (can be applied to a simple classification tree model (Asturiol et al., 2016) and to more complex models such as those based on neural networks (Hirota et al., 2015)).

It is expected that these DAs will gain OECD acceptance by the end of 2019 and that, for the first time, computational methods will be included in an OECD test guideline and fall under MAD.

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Employment effect of innovation

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In setting the Europe 2020 Strategy, the European Union (EU) has defined five ambitious objectives – on employment, innovation, education, social inclusion and climate/energy – to be reached by 2020 (European Commission, 2013). Concerning the first two targets, the Strategy aims at: (i) increasing employment by raising the employmentrate of population to at least 75%; and (ii) promoting innovation by increasing research and innovation expenditures to at least 3% of the GDP.

In the context of these two Europe 2020 Strategy's objectives, an important policy question arises whether innovation and employment processes can be complementary and hence their EU targets can be achieved at the same time? Further, policy makers are interested to know: (i) are there R&D intensity levels when innovation and employment are positively related to each other and when innovation may have an adverse impact on the firm employment? (ii) what type of innovators create most jobs and hence provide the highest potential for policy synergies? Answering these questions is the main objective of the present study, as they may help to design policies, which can efficiently contribute to achieving both the innovation and employment targets of the Europe 2020 Strategy at the same time.

At a first glance, a simultaneous boosting of both employment and innovation may seem an easy and most natural task to achieve as any type of investments (including R&D) increases the labour demand, at least in the short-run. However, the theoretical literature suggests that the relationship between innovation and employment seems to be far more complicated than one can naively assume initially (Smolny, 1998). Also the econometric results reported in the literature on employment effects of innovation are rather contradictory both with respect to their sign and magnitude, suggesting that increasing the innovation intensity can have not only complementary but also substitutionary effects on employment (Young, 1993; Piva and Vivarelli, 2005; Antonucci and Pianta, 2002; Van Reenen, 1997).

In order to accommodate a wide range of possibilities in the innovation-employment relationship ranging from highly negative to strongly positive, in the present study we propose an alternative methodological approach that has not been employed in the innovation-employment literature before. In particular, we relax the linearity assumption in the functional relationship between innovation and employment and hope that it will contribute towards sorting out the likely reasons for observing such a large range of estimated employment elasticities with respect to the firm innovation activity.

We rely on a flexible semi-parametric method – the generalised propensity score (GPS) estimator – suggested by Hirano and Imbens (2004). Two main features of the GPS methodology make it particularly attractive for our purpose: (i) estimation can be based on a flexible semi-parametric regression allowing for a non-linear dependence between the variables of interest without imposing any a priori restrictions; and (ii) the elimination of the selection bias arising from a non-random assignment of treatment (R&D expenditure) intensity across firms by conditioning on the observed firm characteristics.

In applying the GPS methodology, we attempt to identify the R&D intensity levels under which innovation can be complementary to employment and under which it may have an adverse impact on employment. To the best of our knowledge, the application of a flexible semi-parametric counterfactual methods to the employment-innovation nexus is the first of this sort in literature and hence constitutes our main contribution to literature.

We base our micro-econometric analysis on a large international firm-level panel data set for OECD countries and our proxy for technology is a measurable and continuous variable, while most of previous studies have relied on either indirect proxies of the technological change or dummy variables (such as the occurrence of product and process innovation). In particular, we employ the EU Industrial R&D Investment Scoreboard data set, which comprises data on the R&D investment, as well as other financial and economic variables for the top 2500 innovators worldwide.

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Forecasting the teaching workforce in Lithuania

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This pilot project to develop a teacher workforce forecasting model was commissioned by the Office of the Government of Lithuania and the Ministry of Education and Science as part of ongoing reforms of the education system in 2017-2018. Project team members from the Ministry and the Research and Higher Education Monitoring and Analysis Centre (MOSTA) worked together with experts from the Structural Reform Support Programme of the European Commission, the Department for Education in England and University College Cork in Ireland.

Anticipating shortages in specific teaching subjects or other areas in the future is crucial for initial teacher training. In order to accommodate demographic and other challenges, strategic decisions need to be made well in advance. Teachers are key to the learning process, therefore, projecting the size of the teaching population that needs an investment in preparation, skills and continuous support is important. The aim of the teacher workforce planning project is to set up a pilot forecasting model that provides short term and midterm forecasts on teacher demand. Up to now, there has been no systematic mechanism to project teacher workforce or to set quotas for publicly funded study placements for initial teacher training.

The population of Lithuania has been declining in recent years and fell to 2.8m in 2018. Demographic changes have been reflected in the pupil population, with a 5 percent decrease between the school years 2012/13 and 2016/17. The biggest decrease can be seen in lower and upper secondary education. This challenge put pressure on the school network resulting in some closures and consolidation. The pupil-teacher ratio in Lithuania is below average OECD figures.

In addition, the teaching workforce is rapidly ageing, nearly half of general education teachers are 50 years and older. If the trend continues, 20 percent of current teaching workforce will be beyond retirement age in 5 years' time. Furthermore, the number of university bachelor degree students graduating from programmes providing teaching qualification decreased almost threefold. Only a small proportion of graduates seek and find employment at schools. Other challenges such as low salaries, weak learning outcomes of Lithuanian pupils and significant urban-rural disparities can be seen.

A sophisticated teacher forecasting model developed by the Department for Education in England as well as experience of teacher forecasting in Ireland was examined and was found to be relevant and useful. Considering the findings of the literature review undertaken, there is general agreement on the major issues that affect teacher supply and demand. Common principles relating to sources of teacher inflow and outflow are prevalent across the literature. Empirical findings by Lithuanian researchers were summarised, however, the use of the results on policy making is not known.

The teacher forecasting model is based on labour demand and supply. In the model, teacher supply is denoted by (a) inflows to the teaching pool such as the projected number of ITT students who successfully graduate and receive employment at

schools, (b) non-qualified teachers entering schools via various sector engagement programmes or those with unknown qualification due to short timeseries (c) inactive qualified teachers who work outside schools and choose to enter or return to school. The demand side has two major elements: 1. Expansion demand described as the total teacher numbers each year needed to accommodate forecast changes in pupil population 2. Substitution demand described as teachers in stock need to be replaced due to death, retirement or resignation.

The model uses administrative data collected from the national registers on teachers, students and pupils. It includes pre-school, general and vocational education teachers and pedagogical staff members. Different levels of detail are used, depending on the model element. This approach addresses the issue of differences that can occur across different levels, for example differences in contact hours in rural or urban schools, class mergers, drop-outs and other factors.

A list of 25 specializations by school type, level of education, post type and teaching subject was made. In total 83% of teachers and pedagogical staff employed during the school year 2017/18 are represented in the model. Short-term as well as mid-term projections are provided for each of 25 specialisations. Baseline and 2 other scenarios are provided.

According to the baseline scenario, a shortage of 98 individuals is projected in 2018/19. The highest shortage (177 teachers) can be seen in teachers for primary schools. Even if all ITT graduates receive employment, a shortage of over 100 teachers would occur. Therefore, other type of short-term measures are needed to cover the shortage. A surplus for Social educators (37) and Pre-school tutors (284) in 2018/19 is expected. However, there might be differences across municipalities that cannot be calculated with the pilot model.

The highest 4-year (2018/19 — 2021/2022) shortage can be seen among Primary school teachers (700 teachers). Other significant shortages in Lithuanian language and Mathematics might reach up to 200 individuals in 4 years' time. The shortage in Pre-primary teachers will more than double in size to 123 individuals. Foreign language teachers (English and Other) will face a shortage of 171 and 159 respectively. Therefore, changes in the ITT student admission might be one of the main keys to overcome shortages in midterm. The surplus for Pre-school tutors is visible across all three scenarios.

The pilot project results were used to inform decisions on school year 2018/19 admissions to initial teacher training programs. The model results are open to the public, users can construct their own scenarios by changing assumptions for a selection of model elements. The results not only provide relevant information for national level policy makers but also provide information on various teacher labour market prospects that are relevant to teacher training providers, students and graduates, local authorities and schools.

The project contributes to evidence-based decision-making in educational planning in Lithuania. In addition, it aims to strengthen the culture of transparency and dialogue among the educational community. To agree on the assumptions, policy reforms and other methodological elements to be changed or added annually, an advisory expert group would play a crucial role in further model and planning cycle developments.

Global governance challenges: a case for big modelling

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Global emergencies present immense policy governance challenges to national, political and operational decision-makers. Modelling and Simulation has been identified as a crucial force multiplier in the development and implementation of preparedness and response measures. Recent years have witnessed an explosion in modelling and simulation tools for policy and decision support for global challenges while emerging technologies such as IoT and remote sensing enable data collection and analysis at an unprecedented scale.

However, despite these significant developments, the current state of the art of forecasting and predictive modelling has overall failed to deliver the effective outcomes expected. This failure may be largely attributed to two major factors.

The first is the grounding of models to data which affects the accuracy and reliability of the simulations. Models are typically developed off line, however new rules, initial conditions and parameters need to be constantly provided to dynamically update and calibrate the models to ensure that they accurately reflect the real situation on the ground as it unfolds. The need for dynamic data driven simulations has been recognised and there have been significant work in this direction culminating in the concepts of Info-Symbiotic or Dynamic Data-Driven Application Systems (DDDAS). DDDAS provides an adaptive feedback loop framework that covers real time collection of data for model adaptation and new initial conditions.

The second is the fragmentation and siloing in model development and utilization. Such fragmentation reflects the silos as defined for the stakeholder organisations and entities by their respective mandate as well the different academic disciplines, technologies and standards. However, whole-of-society challenges that involve a whole-of-government response are Systems-of-Systems complex problems. The complexity and scale of such systems calls for an integrated approach which would bring all the different elements together to enable a holistic view and analysis. Siloed approaches to modelling isolated processes and phenomena at fixed macro-scales are not sufficient to understand the dynamics of such systems. Instead what is needed to understand the overall system dynamics, gain insights and develop the required predictive capacity is the integration of different models so that the entire set of actors and factors whose interplay at finer spatio-temporal scales creates the emergent dynamics of the system can be analysed in context (butterfly effect). In addition to contextual analytics, the value-added an integrated approach to modelling and simulation could provide stems from the need to be able to reconfigure modelling & simulation inputs and outputs including those not normally anticipated

This paper aspires to conceptualise the need for a data-driven, integrated approach to modelling and simulation for global challenge governance. It does this by proposing a computational framework that link together the different elements of a fragmented landscape and support a holistic approach to decision making. The paper coins the term 'Big Modelling' to describe such large-scale ecosystems of models, simulations and data. Big Modelling invokes a new framework since the challenges well exceed the capabilities of conventional analytics approaches and call for an intermingling of scalable data infrastructures and analytics with multi-scale, distributed and agent based simulations engines for the creation of digital twins (Big Model Twins) at a very large scale.

Modelling European economy as an ecosystem of contracts for smart policy making

Telesca L., Hazard J., Trakti

'*We are moving from the old ways of measuring and reporting growth based on making and selling things (i.e., physical capital), rather than today's growth drivers of developing and creating human, intellectual, and network capital... Our research ... clearly indicates a world where networks and digital assets are more valuable than things and 'access' is more convenient than ownership. In the process of creating more efficient, happy, and technologically supported lives, we may have to blow up and recreate how we gauge economic prosperity and growth.*'[1] [2].

In a world dominated by internet/technology giants the challenge for the European Commission and other policy and regulatory bodies in the world is mostly related to the inconsistency of current economic indicators in supporting the legislative activities in many different policy areas. Economic measurement approaches, and in particular Gross Domestic Product (GDP), with the evolution of todays economies (from industrial to services to information to network), struggles to account for today's intangible assets—services, insights, and networks. This is not just because the way of measuring GDP and Generally Accepted Accounting Principles (GAAP) are not anymore valid methods for measuring economic growth. Although current measures are presenting to the world a difficult trajectory to digest, that tells that we are all headed into negative territory, we believe those methodologies need to be updated and reflected by new contract structures that could facilitate and make measurable and visible the way intangible assets and data are should be correctly accounted in the European open ledger of value.

In particular, with the advent of the digital economy, assessing the impact of a change in rules is becoming more and more challenging. As an example, some regulations impact the relative importance of some actors in networks, because of a variety of reasons (competition, consumer rights or other). The changes and impact may be difficult to see using GDP since it does not integrate the wealth of data produced by networks and market structures, that are increasingly intangible and digitalized. Networked analyses and counterparty information, together with all the other data available are not currently used by regulators and public actors for policy making. In contrast, private sector actors (large and small companies) are using the power of data (big data) for real time decision-making and consider more than accounting values or GDP data in analysing markets and spot market opportunities. Private sector actors understand that data and relationships constitute much of the real value of today's networked economy.

As known, the GDP is aggregated vertically from individual transactions. It measures the reward to factors of production over a given time span, typically a calendar year. In the case of many policies the European Commission is working on, such a distribution of the economic wealth created in a calendar may not be much impacted at all. All this because with the digitalisation of the society some new elements are becoming increasingly important.

In this context, the servification[3] of the industries is making more difficult to track and trace knowledge, data and value based on this networked economy paradigm. This is because economic players adopted new business strategies, totally digital,

1 Libert, Barry, & Beck, Megan, 'GDP Is a Wildly Flawed Measure for the Digital Age', *Harvard Business Review*, https://hbr.org/2016/07/gdp-is-a-wildly-flawed-measure-for-the-digital-age

2 Libert, Barry, & Beck, Megan, *The Network Imperative: How to Grow Survive and Grow in the Age of Digital Business Models*, Harvard Review Business Press

3 https://books.google.it/books?id=1ZW5BQAAQBAJ&pg=PA13&lpg=PA13&dq=servification+definition&source=bl&ots=iENeQfGhRx&sig=ACfU3U3xYRrqG4ubDZQBbap2f7eYQz0cHg&hl=it&sa=X&ved=2ahUKEwicmf65sNfiAhUG3aQKHSlEB14Q6AEwBHoECAkQAQ#v=onepage&q=servification%20definition&f=false

leveraging on new distributions and value capturing models (Servification of the industries, Data economy) that exploit the technological advancements like Service Virtualization, Microservices, Platformization of the organizations. Actors like Google, Amazon and Facebook drove those trends to create new collaborative models and business opportunities. This happened since they understood the value of data and the possibility to digitalise relationships and services creating new opportunities for atomic transactions. Furthermore, with the advent of blockchainbased applications and services we will see more and more tokenised securities, rights and assets that will disrupt again the relationship between ownership and transfer of value.

The impact of knowledge, software and data are affecting the soundness of GDP as a comprehensive measure to monitor and asses the wealth of nations. GDP is not invalid, but is less helpful because the data economy is more fluid and not measured correctly by today's accounting principles. Therefore to create a better framework for policy making and monitoring, we need to leverage data and enhance current economic indicators with network and contracts information that could give us a better playing field to test and assess the impact of policies that EU institutions would like to implement in the market.

With our work we want to demonstrate how an innovative approach can be used both for reporting the European economy as an ecosystem of contracts and as an actual way to describe the connection between the legal and accounting world, basically a boundary object between the two worlds. It is radically more efficient and has the ability to provide precise, qualitative and quantitative measures of contracting across the entire European economy connecting relationships, data, legal and economic frameworks. In our research we use the term 'contracting' in a very large sense to include quasi-contracting, permits, approvals, payments and governance documents, roughly coextensive with the notions of 'contract' in economic literature such as that of Ronald Coase's theory of the firm[4] and of Hart and Holmstrom's theory of contract incompleteness[5].

The approach is similar to those that leading-edge enterprises are beginning to adopt – a 'graph' of semantically-labelled data, organised into secure 'data lakes,' with cryptographic access control and assurances of coherence of data across suppliers, customers, managers and regulators, based on standards and open source software[6]. In essence, our approach demonstrates that an entire economy can be modelled in the way that leading enterprises are modelling their own commercial relationships

Modelling the social impact of open access knowledge repositories

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Ex-ante social impact assessment is increasingly relevant in the design of advanced cloud-based knowledge provision systems (OKPS) involving a large number of users. OKPS are an important subclass of 'ICT-enabled social innovations' [2]. Their importance is due to the fact that they are capable of reaching diverse social policy goals in a timely, relatively low-cost manner, and according to common citizens' preferences. This is due to a rapidly developing ICT aligned with the high and ever-growing digital literacy in the European societies, a common access to broadband Internet via mobile networks, and a rich offer of web-based applications. Therefore the expected impact of OKPS financed from public funds is a key decision factor when designing social and digital policies at regional, national and EU-levels.

4 Coase, R. H. (1937), 'The Nature of the Firm'. *Economica*, 4: 386–405. doi:10.1111/j.1468-0335.1937.tb00002.x

5 O.Hart, 'Incomplete Contracts and Control', *American Economic Review* 2017, 107(7): 1731–1752 https://doi.org/10.1257/aer.107.7.1731, Hart, Oliver, and Bengt Holmström. 2010. 'A Theory of Firm Scope.' *Quarterly Journal of Economics* 125 (2): 483–513

6 https://www.oreilly.com/ideas/fishing-for-graphs-in-a-hadoop-data-lake

An innovative digital knowledge repository developed within a recent project of the EU-financed Horizon 2020 research programme [3] can serve as an example of such a social innovation. One of the ultimate goals of this repository is to provide an efficient training and research support tool for students and young researchers. Its user community building approach presumes a wide use of existing cooperation networks centred around current research projects, student organizations, and exploring the opportunities offered by social media.

Based on the assumption that the social impact of the repository will grow with the number of satisfied users, the efficiency of disseminating the information about the content and functionalities offered to potential users plays a major role in impact optimization. Thus arises a three-level model of user community building and maintenance.

At the user level, the information about an OKPS is disseminated spontaneously via social information diffusion and user community growth according to the snowball principle. The latter will be formally described by learning cellular automata [1]. A simulation procedure calculates the impact of individual community-building activities and sums them up over a planning period. Moreover, the cooperation results of agents involved in the repository operation on user group development require synergetic models capable of aggregating individual actions and taking into account non-linearity arising from their interference. This makes possible a transition to the meso modelling level, where the interactions inside of different user groups are modelled as cellular networks of controlled discrete-event systems (CDES). When performing the simulation at the meso level, CDES agent-based models are coupled with anticipatory networks (AN, [6]). The latter serve as a long-term impact assessment and policy planning tool. Based on the experience gained within the project [3], ANs built with Delphi outcomes [5] turned out to be particularly suitable for the overall impact modelling and optimization of OKPS. The ANs simultaneously formalize backcasting combined with scenario planning and anticipatory impact models in multicriteria decision processes.

At the macro level, where the impact of individual OKPS will be aggregated, a hybrid stochastic discrete time control model of the user community growth at the learning group or its partition level can be used. Statistical models of global DES influence [4] can be also used for cases where the dissemination activities are addressed to large groups of anonymous and mutually independent individuals, such as Internet ad campaigns or TV broadcasts.

Another mechanism contributing to the positive impact and user community building, is the provision of attractive, novel and efficient tools, repository services and functionalities. The uses of them will provide users' feedback indicating the direction in which the services will evolve so that they better fulfil the needs and expectations of different user target groups, stakeholders, and policy goals. According to [7], strategic goal attainment can be evaluated by the set of quantitative criteria which should fulfil the following conditions:

- better values of each criterion correspond to a higher satisfaction of user or stakeholder preferences regarding the project goals (representativeness),
- every change in user or stakeholder satisfaction as regards goal attainment can be expressed equivalently as a change in values of at least one of the criteria (completeness),and if multiple redundant criteria with stochastic errors describe the attainment of the same goal, they must be independent random variables (weak non-redundancy).

The social policy goals of the OKPS defined in the Digital Agenda 2020 and the EC Social Investment Package (SIP) will be fostered with increased learning and rese-arch efficiency and a higher level of innovativeness. SIP defines the Social Investment for Growth and Cohesion as an initiative to delivering, among the others, high levels of employment, productivity and social cohesion. These are among the social goals of many OKPS, including the repository [3] which primary goal is reaching a 'decisive impact on the innovative capacity of the European society' [3]. The 'impact of design decisions on learning effectiveness' is the secondary social goal that directly addresses user and institutional stakeholder satisfaction with the repository-supported learning. In addition to individual and group users, any public organizations such as schools, hospitals, business and innovation support institutions can be repository's stakeholders. The social impact builds on the principle that innovation leadership knowledge acquired by the users increases their overall productivity and creativity.

Furthermore, the OKPS design, implementation, and operation should conform to the general objectives of research policies, specifically those included in the underlying documents of Horizon 2020 and Horizon Europe. For example, 'improving the quality of collaborative research and innovation among the EU research institutions' is a requirement that should conform to many OKPS project goals. The above social goals can be quantified and included in the formulation of optimisation problems, where the portfolio of OKPS project, the guidelines to design individual knowledge repositories and planning of operational activities of repository managements may occur as following specific goals G_j:

G_1 - reaching a given number of satisfied users,

G_2 - reaching the prescribed number and quality of services offered,

G_3 - reaching the content quality and quantity in predefined fields that is assessed as satisfactory by the users.

Finally, an analysis of user responses to various service innovations and community building activities may provide clues concerning the efficiency of social educational and digital policies implemented at different levels.

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PIRAMID: a new methodology to build baselines for CGE models

Wojtowicz K., Rey Los Santos L., Vandyck T., Tamba M., Weitzel M., Saveyn B., European Commission, Joint Research Centre
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Computable General Equilibrium (CGE) models have become one of the most used tools for economic analysis. Originally CGE models were developed for short-term policy assessment such as fiscal and trade policies. In this context, base year economic structure was suitable for the comparison of policy scenarios. More recently, the need to address long-term-issues, such as energy and climate policies, has motivated the development of dynamic CGE models. When analysing long-term policies, base year economic structure may not be valid and, therefore, baselines are required to assess the implication of different policies in the future. A baseline describes the evolution of the economy without additional policies and serves as a benchmark for assessing economic, energy and climate policies.

The increasing interest in dynamic models has led to an increasing interest in baselines. It is well known that the numeric results of a model are very dependent on the economic structure and, thus, baselines are essential for any comparison exercise. For example, the cost of a climate mitigation policy in 2050 will depend on the preferences, productivities, efficiencies and technological options assumed in the reference path. Although the importance of the baselines is well known, still there is a wide range of different methodologies which try to build a baseline. This lack of consensus hinders the comparative assessment between models.

Roughly speaking, conventional baselines are built in two steps. First, base year data is used to calibrate the parameters of the model. Then, production factors, productivities and key parameters of the model are projected over time to meet exogenously determined targets, such as GDP, GHGs emissions, etc. In our opinion, this approach presents two drawbacks. First, the baseline is dependent on the base year data and may not be able to reflect structural changes in the economy (e.g. new technologies). Second, baselines are created using a model and, therefore, are dependent on the structure of that model. This makes it difficult for other modelling teams to replicate the same baseline.

This paper presents an alternative methodology to build a baseline. We propose to reverse the order of the two steps in the conventional baseline building. In our methodology, firstly, base year data structure (Input-Output tables) is projected over time and then, the parameters of the model are calibrated for each period. This approach requires the projection of all data conventionally used to calibrate a model. On the other hand, it provides the flexibility to set the values of the main variables of the model and control the economic structure in the baseline.

Most of the data commonly used to calibrate a CGE model is gathered in the Social Accounting Matrix (SAM) and, therefore, is the key element of our projections. The base year SAM is usually built from GTAP database, which is also the benchmark for our projections. The methodology used to project the SAM is the Multi-Regional Generalized RAS (MRGRAS), and extension of the well-known RAS method.

The projection of the SAM is subject to macroeconomic assumptions: GDP (Private and Public Consumption, Investment, Exports and Imports), tax rates, capital and labour payments, labour force, unemployment rates, population, etc. These data are obtained from external sources and, ideally, should be consistent. In addition to the macroeconomic assumptions, we also impose energy data projections from partial equilibrium energy models such as POLES, PRIMES and/or POTENCIA. We fix the use and production of energy products in the SAM. Energy data is balanced not only in value terms but also in quantities and, thus, we can replicate CO_2 emissions estimated in energy models.

To our knowledge, this is the first attempt to create a baseline for CGE models projecting base year data. This methodology presents three advantages compared to conventional baselines:

1. **Flexibility**. It allows for a better control of the variables we are interested in and for introducing structural changes.
2. **Reproducibility**. The projected SAMs are not model dependant and can be used by other modelling teams.
3. **Transparency**. The baseline is built based on transparent macroeconomic assumptions and energy data. In case of discrepancy, these assumptions can be corrected and improved.

Plenary session 2

Room 0.A
27 November
09:30 – 10:30

Assessing social impacts of policies: indicators and methods

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The ex ante impact assessment of policies has become a standard procedure of the policy making process within the European Commission as well as in many countries across the globe. What has begun in many countries as an analysis of the economic costs of regulation, has now been expanded as a comprehensive assessment of all economic, environmental and social impacts of planned policies. The analysis of the expected impacts and the comparison of different policy options based on scientific methods and evidence should inform policy makers and politicians about the likely consequences of their actions. It should also inform stakeholders and the public about the net benefits of a planned policy.

The assessment of economic and budgetary impacts can build on solid databases and elaborated modelling tools. For many (not all) environmental aspects, similar capacities have been developed. For both dimensions, there is an articulated demand from policy makers and stakeholders to summarize the evidence on likely impacts.

For social aspects, the situation is different. The social dimension is in many policy impact assessments the least elaborated. There could be several reasons for this: Missing tools and data, a lack of demand or a poor conceptualisation of social impacts. Unlike for economic and environmental impacts, for social aspects it is often not straightforward to attribute social impacts as a desired outcome or not. The acceptable level of inequality in society, sources of individual well-being, even the marginal value of income is a matter of diverging perspectives. Hence, unlike for economic impacts, the distinction between unwanted and desired impacts is in many cases not straight forward.

There are, however, good arguments to improve the evidence base for policy making also for this dimension. Firstly, because policies that imply a structural change to society, i.e. create winners and losers, have to be assessed against the benefits to society as a whole. It should be asked in how far the gains for one group could compensate the losses for others. Furthermore, impacts on those groups that are not organized and thereby cannot articulate their interests needs special attention.

A social impact assessment would ask for processes that are triggered or changed by policies and their impacts on different groups in society. Typical classes of processes are

- Changes in economic processes
- Changes in natural systems
- Geographical changes
- Demographic changes
- Institutional changes
- Emancipatory changes

The list shows that social impacts are closely interlinked with economic and environmental aspects of an impact assessment.

The impact categories are, however, different. Social impacts include:

- Health and wellbeing
- Income
- Social environment
- Impacts on family and community
- Institutional and political impacts

Finally, groups can be distinguished along different characteristics, e.g.

- Socio-economic and demographic status
- Types of households
- Position in the economic system
- Property rights
- Geographical aspects
- Preferences

Socio-economic aspects are far more often analysed than those aspects that are related to societal participation. Typical indicators for socio-economic aspects are income, employment or health. Participation, social cohesion and well-being in society is, however, not only a matter of income, but also a matter of access to social processes and has a cultural dimension. These aspects are far less often considered in impact assessments. They would require a qualitative approach to impact assessment. Although comprehensive indicators on well-being have been developed, the cause to effect relation is most often unclear and often contingent to the contexts. Therefore, qualitative methods that answer such questions should be considered in the standard repertoire of Impact Assessments.

The talk includes examples for impact assessments using microsimulations for the analysis of socio-economic impacts, indicators and indices for well-being and examples for applying qualitative methods.

Parallel sessions 4

Complex system modelling and multi-criteria decision making 2

Room 0.A
27 November
11:00 – 12:30

Making sustainability models more robust: dealing with the complexity of the metabolic pattern of social-ecological systems

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Problem framing

The practical consequences of ignoring the implications of complexity in developing quantitative analysis for sustainability policies are illustrated with three blatant cases:

1. *Used Cooking Oil (UCO)*. The implementation of the revised Renewable Energy Directive (RED II) is under scrutiny: UCO has been mixed with palm oil to take advantage of favourable policies[1]. This fraud could have been anticipated if the relation between primary sources and secondary energy carriers had been considered. (i) Availability of cooking oil (primary source) in the EU is about 5–6 kg per capita/year. Of this, only 3–4 kg are theoretically recoverable as UCO. (Austria is the EU country that recovers most UCO with 1 kg p.c. per year). (ii) The production process of secondary carriers (the biodiesel) entails that only 75% of the UCO can be transformed in biofuel and only 70% of the energy of this biofuel is net (because of the energy consumed in the process itself). Hence, the estimated production of biodiesel per capita per year from UCO in the EU is between 0.5 kg (1 x 0.75 x 0.7 using the Austrian 'best practice') and 2 kg (assuming an unlikely quadrupling of this benchmark). In conclusion, UCO is a waste management problem, not an alternative energy source.

2. *Use of the Economic Energy Intensity (EEI)* to study decoupling. The EEI is a combination of two strongly correlated indicators: (i) gross inland energy use per capita and (ii) GDP p.c. per year. The following groups of countries each have a same value of EEI: (1) Guatemala, the Netherlands, Germany, Angola, Norway, Chile; (2) Sweden, Macedonia, France Azerbaijan, Egypt, Argentina; (3) Australia, Algeria, Finland, Malaysia, USA, Turkey[2]. This shows that, at the national level, the EEI does not have any discriminatory power to characterize societal performance. Why then is the EEI expected to provide useful information for studying the energy performance of countries?

3. *EU scenarios of decarbonization*. The scenarios provided by the EU predict a monotonic decrease of emissions from now to the year 2050[3]. Such a dramatic reduction in emissions requires a radical and quick transformation of the whole economy. The vast majority of power capacity for both production and consumption of energy carriers will have to be replaced in less than 30 years using fossil energy. However, no emissions for this Olympic effort are considered in the scenarios. What type of models have been used?

Some systemic epistemological blunders emerge from these examples:

1. Ignoring the forced State-Pressure relation between primary energy sources and secondary energy carriers (UCO case). One cannot study energy systems without adopting simultaneously non-equivalent metrics: For studying external constraints – primary sources; for studying internal constraints – the process of production and use of energy carriers;

2. Ignoring the multi-scale and open nature of complex adaptive systems organized across different levels. Looking only at one level of analysis and ignoring the openness of the system results in simplistic representations.

1 https://www.euractiv.com/section/agriculture-food/news/eu-throws-the-ball-to-member-states-to-monitor-red-ii-implementation/

2 https://doi.org/10.1016/j.jclepro.2012.12.031

3 https://ec.europa.eu/clima/policies/strategies/2050_en

3. Ignoring the biophysical roots of the economic process entails missing the side effects of important transformations, such as rapid decarbonization. Changing the quantity and quality of flows requires changing the quantity and quality of the fund elements that produce (power plants), deliver (batteries, distribution lines) and use these flows (e.g., means of transport, infrastructure and appliances in residential, industrial processes). The production, maintenance and replacement of fund elements must always be considered, in terms of both emissions and energy requirements.

Can we do better?

A different generation of quantitative models is needed to obtain relevant information for sustainability. These models must establish a series of bridges across non-equivalent representations of the performance of energy systems:

1. Between final energy consumption and material standard of living by looking at internal end-uses across levels. The relevant information here is: (i) who uses what energy carriers, (ii) how effective is their use (qualitative); (iii) how much of each type of carrier is used (quantitative); (iv) what is the purpose of each end-use (the functions associated with energy uses).

2. Between the environmental pressures associated with the energy end-uses in society and impacts by looking at local effects of the pressures (use of primary sources and sinks) on the integrity of ecological funds. The relevant information here is about tracking across levels and scales (in GIS) the different pressures in relation to resulting environmental impacts.

3. The level of externalization of the energy system by looking at dependency on imports (security aspect) and externalization of emissions and impacts to other social-ecological systems (ethical aspect). Relevant information here is: (i) what are the available primary sources and sinks for domestic production? (ii) what are the imports of both primary sources and secondary carriers?

This new generation of quantitative analysis is being developed in the Horizon 2020 project 'Moving towards Adaptive Governance in Complexity: Informing Nexus Security' (MAGIC). Its analytical tool kit combines five conceptual tools that integrate the use of non-equivalent metrics:

1. local end-use matrix (how society uses energy, water, food, labor and land) across its internal components);

2. bio-economic pressure matrix (what share of the total consumption of secondary input goes in boosting the material standard of living);

3. local environmental pressure matrix (the use of primary sources and sinks affecting the integrity of local ecological funds);

4. externalized end-use matrix (the secondary inputs used by the exporting society embodied in imported products and services);

5. externalized environmental pressure matrix (the primary sources and sinks embodied in imported products and services).

MAGIC's accounting method uses concepts from complexity (relational analysis, hierarchy theory, bioeconomics) to characterize the metabolic pattern of social-ecological systems. It is transparent in terms of assumptions and data used to integrate information across scales related to: (i) the energy, water, food, land nexus; (ii) different types of environmental loadings/impacts; (iii) demographic and socio-economic variables. It also integrates the analysis of industrial, urban and household metabolism in terms of social practices. These concepts will be illustrated using applications developed in the MAGIC project.

Supporting result-based schemes. The case of ex-post assessment of agri-environmental-climatic schemes

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The current Common Agricultural Policy (CAP) architecture includes three measures that aim to not only improve positive environmental externalities but also reduce negative environmental externalities: a) cross-compliance, b) greening, and c) agri-environmental climatic schemes (AECS). The proposal for the post-2020 CAP indicates a more flexible and results-based approach (i.e. measures that focus on payments for results achieved), giving member states more room to manoeuvre to adapt measures to local conditions and environmental priorities. This debate has pushed more focus to AECS design by highlighting results-based measures with payments designed based on the environmental quality provided.

The results-based approach renews the role of research in providing reliable ex-post analyses to enable the tracking of changes in environmental quality due to agricultural practices and measuring the contribution of the CAP measures to these changes. Measurements of environmental performance and the causal effect of AECSs on environmental performance are largely debated at the academic and political levels. However, the existing evaluation and monitoring system seems unsuitable for supporting this new role of evaluation. Although the impact of the CAP on sustainability is traditionally addressed by the agricultural economics literature, its contribution to the environment quality is still debated, and the literature has not converged to a consensus. Two factors can contribute to the difficulty of comparing the findings of different studies: the use of case studies and the application of different methodologies. First, a majority of studies are based on case studies which apply different proxies for environmental quality changes, and few studies use composite and overall indicators. Second, existing studies apply several methodologies with a plethora of alternative assumptions and restrictions. The methods differ in terms of the data used, the measurement proxy for environmental changes, the possibility of building a counterfactual, the complexity in creating policy scenarios, and, finally, the interpretation of causality. The literature highlights several causes and barriers which can reduce the expected benefit of an AECS. These motivations can encompass both policy failures (in each step of the policy cycle) in private motivation and opportunistic behaviour as well as in asymmetric information.

Against this background, we estimate a composite indicator of high nature value at farm level (HNVf) that enables us to track changes at the farm level, and then assess the contribution of AECSs to these changes ex post. We use a sample of panel data from the Farm Accountancy Data Network (FADN) for two Italian regions (i.e. Veneto e Tuscany) from 2008 to 2014. In this study, we estimate the effects of different payment levels on a subgroup of farms by applying the generalised propensity score (GPS) approach. More specifically, we first estimate the GPS using a generalised linear model, and we then estimate the dose–response function using a flexible parametric form for the regression function of the outcome on the treatment and the GPS. As AECS payments are tailored to compensate for foregone costs and income due to participation in environmentally friendly measures, we assume that the benefit expected from these schemes increases linearly with the payment received. Thus, we want to observe whether increasing payment levels leads to further environmental benefits or, alternatively, if some sub-optimal payment levels do not maximise environmental benefits because of the relationship between several sources of failure that can arise in designing AECSs.

Our results demonstrate that several agricultural systems and payment levels affect the provision of HNVf. The results show a significant effect of agri-environmental schemes on composite indicators of HNV but an uneven distribution across various payment levels. Our results confirm puzzling evidence regarding the effect of AECS payments, as alternative payment levels have different impacts on HNV. Altogether, the results confirm previous studies showing an overall positive effect of AECSs on HNV, but a lack of design and targeting (Raggi et al. 2015) and an agency problem (Bartolini et al. 2012) lead to a lower impact of the measures. Our results can contribute to the debate on the effectiveness of different types of measures, showing that narrow and deep measures might bring higher environmental benefits at the farm level. However, the results justify further additional public transaction costs for improving AECSs' tailoring and targeting. In fact, our results show that the instrumental mix results in a higher provision of an environmental good but requires better coordination and communication to farmers.

Using an evidence-based approach to support policy reform remains a central topic in policy discourse and is now legally established within the new delivery model. Consequently, further development in understanding causal mechanisms within the CAP is necessary. In this study, we aimed to contribute to that debate by developing a methodology that enables us to account for the multidimensionality of the provision of public goods and measure the causality of public expenditure. Thus, although the transition towards more results-based policy design is desirable to better understand the linkage between payments and environmental performance, the current methodologies and the data collection infrastructure are not completely satisfactory for ensuring the application of results-based payments. Moreover, our study indicates a rather large complexity in detecting policy failures based on ex-post data owing to several difficulties in disentangling the effect of each cause of failure. This calls for the use of a different evaluation process for AECSs, perhaps by combining advanced modelling of the causality of AECSs with reflexive exercises by engaging the relevant actors and stakeholders.

Exploring the (non-)use and influence of models in Belgian climate policy-making: a multiple case study

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Since various public and private actors at the international, supranational, national and subnational levels started to adopt long-term targets for reducing greenhouse gas emissions, low-carbon scenario analyses have flourished. Literature reveals an increasing number of model-based analyses envisioning and exploring alternative images of low-carbon futures, as well as their adjacent transition pathways. Scenario approaches or 'foresight' is intended to help policy-makers to navigate the maelstrom of confusion and conflicts associated with highly complex societal challenges such as climate change — i.e. the 'super-wicked' problems. Typical scenario exercises aim at coping with uncertainty and conflicting values, and hence are often claimed as a suitable approach for knowing and governing super-wicked problems.

When reviewing the scenario literature published over the recent years, we observe significant methodological developments, in particular at the level of the calculus or data-sets. These contributions have generated an increasing technical sophistication of models and scenario building methods, which contrasts with the relative absence of social sciences research on scenarios. Scenario analyses have received little academic attention from social sciences, whether they are political science, sociology, philosophy of science or STS. More specifically, even if foresight products and processes are claimed as potentially contributing to policy-making, relatively little empirical efforts have up to here tried to explore the fundaments of the role of the scenario analyses throughout the policy cycle. The present paper aims at contributing to fill this research gap.

The research questions are formulated as follows: How are low-carbon scenarios used by political actors? Beyond the purely instrumental use, how do these foresight exercises influence policy-making? How do the different actors appropriate the representations of the future developed through these scenario analyses? What are the factors that affect the use and influence of these foresight exercises in policy-making?

The paper rests on a multiple case study analyzing the role in policy-making of four energy foresight studies carried out for Belgium. The chosen studies differ inter alia in terms of clients, contractors, year of publication, scope, approach (i.e. forecasting or backcasting), methodology (i.e. bottom-up modelling, top-down modelling or qualitative methodology inspired by the work of the French prospectivists Hugues de Jouvenel and Michel Godet), level of participation and actors involved (i.e. from expert-based analysis to participative exercises), product, communication strategy, and follow-up. The analysis has been carried out on the basis of an analytical framework developed in the knowledge utilization literature (see Gudmunson & al., 2009). This framework considers five types of knowledge role in policy-making, namely instrumental, conceptual, political, process and distortive roles. The exploration of the use and influence of low-carbon scenarios in policy-making is based on documentary analysis and 74 semi-structured interviews with the actors involved in the long-term climate mitigation policy in Belgium. Those actors are political authorities, political advisors, administrative authorities, employers' federations, workers' unions, environmental and development NGOs, advisory councils, energy market operators, public transport operators, public research institutes, consultancy agencies and universities. The important empirical material collected was analyzed with the method of thematic coding. After exploring the role in policy-making and the level of appropriation per actor for each of the four foresight studies, I have conducted a cross-case analysis in order to highlight the similarities and differences between the four studies.

The cross-case analysis reveals that the role in policy-making varies strongly from one foresight study to another. However, few examples of purely instrumental use of studies as orientation and decision support tools to devise mitigation policies are noted. Studies are rather used to justify decisions already taken or to improve someone's relative position in the policy systems compared to opponents (i.e. political role). Studies also contribute to expand the knowledge base and introduce new ideas or concept in policy (i.e. conceptual role). Moreover, even if none of the analyzed studies rest on real exercise of scenarios co-construction, some studies still have a process role. The implementation gap between low-carbon scenarios and policy is not surprising since the relationship between sciences and policy is neither linear, nor mechanic — the vision of a rational knowledge-based policy-making model being rather naïve. The purely instrumental use of scientific knowledge in policy-making is generally quite limited, especially in highly politicized context like Belgium. Instead, knowledge usually has a more diffuse and indirect influence on policy-making — i.e. conceptual and process roles. That said, in the present research, such conceptual and process roles were observed among nearly all the actors, political authorities excepted. The cross-case analysis actually shows that the level of appropriation of foresight studies varies greatly from one actor to another, and that the public actors within administrations seem to be more permeable to the investigated foreknowledge, whereas, on the contrary, political authorities mark little interest in the scenario exercises. Finally, the cross-case analysis suggests that a specific constellation of factors contributes in explaining the (non-)use and influence of each study. That being said, it seems that the particular characteristics of each study affect less the role of the studies in policy-making than contextual factors.

The last section of the paper focuses more specifically on the factors that can contribute to explain the very low level of appropriation of low-carbon scenarios by political authorities. In this discussion, I explain that the low levels of interest of political authorities in low-carbon scenarios can be related to the very nature of both foresight and climate mitigation governance. On the one hand, I highlight a mismatch between foresight and policy-making that makes the integration of foresight in political practices difficult — if not impossible. On the other hand, I point out a number of challenges inherent to climate mitigation governance that lead to political inertia.

In turn, by providing empirical insights on the (non-)use and influence of model-based scenario analyses in policy-making, the paper could be instrumental in learning for the modelling community.

Assessing the potential of machine learning algorithms for agent-based models from an innovation policy perspective

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Especially in the field of evolutionary/neo-Schumpeterian innovation economics, agent-based modelling (ABM) has been recognized as one of the most promising tools for investigating and capturing the complex nature and resulting dynamics of processes related to innovation activities (Morone and Taylor 2010). While using agent-based models without doubt helps improving the understanding of the dynamic relations between micro-processes and the emergence of macro patterns, researchers generally face a trade-off when applying ABM to complex phenomena such as innovation processes. ABM allows for creating complex models that omit the underlying restrictions of traditional economic modelling approaches. With ABM we have a tool at hand that is flexible, that provides a natural description of the real world and that is able to capture emerging phenomena. However, the complexity of models created through an ABM approach is limited by our capability to analyse and understand the respective models' output. If the complexity of the model is reaching a level where we are no longer able to understand the processes involved, we cannot understand these artificial complex systems any better than we understand the real ones (Gilbert and Terna 2000; Axtell and Epstein 1994). At this point, the model decays to a meaningless construct without any real scientific value, which in the best case can be used to visualise our little understanding of the matter. Consequently, our ability to analyse the output of complex agent-based models over a large set of different parameters becomes a bottleneck, especially when applying ABM for innovation policy purposes.

One approach that may help us overcoming the natural limitations of traditional means of output analysis are recent advances in the broad field of machine learning and data-mining tools. These tools may complement ABMs, especially in the analysis, of model outcomes (van der Hoog 2018). Potential applications of machine-learning algorithms for ABMs are manifolds. They range from variable selection (e.g. Pereda et al. 2017; Edmonds and Lessard-Phillips 2014; Patel et al. 2018) to the use of machine-learning tools for validation/verification of ABMs (e.g. Baqueiro et al. 2009; Remondino and Correndo 2006), or even to the automated analysis of results by emulating the behaviour of the whole model (van der Hoog 2017).

In our paper, we aim at identifying the potential of using machine-learning algorithms for complementing agent-based models in innovation policy research. To be more precise, we explicitly try to answer: 'Which potential role can machine learning play in innovation research, in general, and how can ANNs help discovering new patterns from big data sets created by agent-based models, in particular?'. To do so we apply a set of machine-learning tools to an agent-based model designed for the systematic exploration of knowledge exchange/learning and the complex processes affected by various types of systemic innovation policy interventions, called VISIBLE model (Virtual Simulation Lab for the Analysis of Investments in Learning and Education) (Pyka et al. 2018; Pyka et al. 2019). Based on this example, we aim to show how

ABM can be used for improving our understanding for the complex interplay of innovation processes and, therefore, for innovation policies.

Preliminary results indicate that the application of machine learning tools to the analysis of ABM outputs offer some interesting insights and may indeed enhance the interpretation of the results as well as the researchers' understanding of specific patterns within the model's output. This, however, only strongly depends on the specific purpose a researcher pursues and within narrow boundaries.

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Machine learning in the service of policy targeting: the case of public credit guarantees

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Machine Learning (ML) tools (Hastie et al., 2009; Varian, 2014) are increasingly used to address prediction problems in applied econometrics. In some instances ML techniques can be used to assist decision makers, by providing them with a decision rule that summarizes the available evidence in order to predict which choice is more likely to serve the purpose. This task is what Kleinberg et al. (2015) define as 'prediction policy problem'. When the decision concerns policy targeting, ML methods can be employed ex-ante to identify, among the potential beneficiaries, those who will likely behave in such a way as to ensure the effectiveness of the intervention.

In this paper, we focus on the 'prediction policy problem' of assigning public credit guarantees to firms. Public guarantee schemes aim to support firms' access to bank credit by providing publicly funded collateral. The literature has highlighted that these schemes often fail to reach firms that are actually credit constrained (see, for instance, Zia, 2008). If the guarantee is provided to firms that are not credit constrained the additionality of the program will languish as these firms would have obtained funding anyway. One of the reasons for this misallocation is that credit rationing is difficult to gauge, while firms' creditworthiness is more easily assessed by means of balance sheet variables. As a result, the eligibility condition usually winds down into naïve rules that pinpoint financially sound borrowers, without considering indicators for credit constraints (OECD, 2013). Our exercise aims at suggesting a benchmark assignment mechanism, based on ML algorithms, that explicitly accounts for both credit constraints and creditworthiness. The nature of this task is essentially a forecasting one. As underscored by Mullainathan and Spiess (2017), these prediction policy problems are the ones for which the ML machinery is extremely well equipped.

We compare our ML-based assignment mechanism against the rule originally put in place. The advantages of the ML tool we propose can be shown by comparing its performance to that of the current allocation rule adopted by the Italian Guarantee Fund (GF) to select firms eligible for public support when accessing credit.

In the first part of the paper, we work as if we were in the ex-ante situation, in which the policymaker must design the allocation of the guarantee without prior knowledge of the intervention effectiveness. We make use of micro-level data from the credit register (CR), kept at the Bank of Italy, and the Cerved (balance-sheet) dataset, and develop two separate ML prediction models, for credit constraints and creditworthiness, respectively. All the variables that we use for predicting each status could be potentially available to the GF administration when a firm applies for the guarantee. We consider a firm to be credit constrained if the total amount of bank loans granted to that firm does not increase in the six months following a new request for bank credit from that firm, while we consider it credit worthy if it does not have adjusted bad loans in the three-year window following the request. We try different ML algorithms to predict each status — LASSO, decision tree, and random forest — and show that the best out-of-sample predictive performances are reached with the latter. The predictions for financially constrained firms are combined with those for creditworthy firms to identify the ML hypothetical beneficiary of the GF. By comparing the GF assignment with the ML assignment, we show that the GF scoring system is biased against firms that are credit constrained.

In the second part of the paper, we substantiate the validity of our approach by looking at the ex-post dimension. As underscored by Athey (2017), ML prediction will not automatically ensure higher program effectiveness because a program might have heterogeneous effects and ML might fail to target those for whom intervention is most beneficial. We provide ex-post empirical evidence to test whether that ML-based assignment mechanism satisfies the aim of increasing the impact of the policy. We start by showing the results from contraction and re-ranking experiments, in the spirit of Kleinberg et al. (2018). Through these exercises we estimate the increased effectiveness that could be attained by excluding some current beneficiaries that are not ML targets, and (under the assumption of selection on observables) by substituting them with firms that are not treated under the GF rules, but that should have been eligible for the collateral according to ML. Next, to relax the selection-on-observables assumption, we exploit the threshold for assignment implied under the GF rules and run a Regression Discontinuity Design (RDD) experiment, separately by ML-targeted and non ML-targeted groups of firms. We find that effectiveness is higher for the firms identified by ML as targets.

We show that around 47 per cent of the resources currently allocated by the GF rule go to firms that are not a target according to our ML algorithms. By channeling these resources to other firms identified as ML-target, the effectiveness of the policy improves significantly.

We discuss the importance, in our case, of other issues that are typically related to the use of ML for policy decisions, such as transparency and omitted payoffs.

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Parallel sessions 4

Engaging stakeholders and policy makers

Room 0.B
27 November
11:00 – 12:30

Complex modelling to achieve carbon neutrality in Portugal

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In 2016, one year after the signature of Paris Agreement, the Portuguese prime-minister undertook the policy goal of transforming Portugal into a carbon-neutral economy by 2050. A team of 28 national scientists and experts from different fields (energy, agriculture, forest, economy) conducted technical studies, including modelling, to support the Roadmap for Carbon Neutrality (RCN2050). This offers the vision and the pathways on how the neutrality goal can be achieved in Portugal, concerning technological options, economic feasibility, and the need for social transformation, while considering circular economy (CE) as central piece.

This paper shows how modelling tools, linked with a deep stakeholders' engagement approaches, have delivered plausible carbon neutral futures to Portugal. RCN2050 was constructed through an integrated framework, embracing five stages.

1. Designing socio-economic storylines and quantification of the underlying indicators. More than 20 national representative stakeholders have co-created plausible visions up to 2050 for the Portuguese society through a structured workshop and direct interviews. Three distinct storylines regarding the country's development were designed: i) Off-Track, Portugal keeps a modest socio-economic growth and is out of the way in the mitigation action; ii) Yellow Jersey, Portugal has a leading position in climate mitigation and in economic development, pushed mostly by creative and knowledge economy, circularity of economy is obtained through the redesign of the productive processes carrying high levels of efficiency; ii) Pack, Portugal moves in block with the majority of EU countries, becoming more efficient and productive although without significant changes in its economic structure, circularity levels increase, resource efficiency is improved, and severe mitigation policies are considered. Each storyline backs a set of socio-economic indicators, validated by key Portuguese officials, including the cabinets of Ministries of Economy, Finance and Environment and the Portuguese Bank, getting them involved along the envisioning process.
2. Gathering key-stakeholders' visions for 2050 through seven visioning workshops covering: mobility, forest, agri-food industry, cities, construction industry, waste and energy. More than 160 participants from more than 100 entities (private companies, central and local government, research institutions and NGO) were involved. These collaborative events allowed to define, corroborate and refine assumptions regarding fundamental activity variables, which represented relevant drivers for the modelling exercises, as was the case of CE assumptions (e.g., efficiency silvicultural practices; recycling rates with impact on waste and on energy technologies; industry production levels, namely cement, glass and paper; households sharing models with effect on household size and equipment's stock).
3. Quantitative assessment of pathways to deliver carbon neutrality by 2050. The greenhouse gas (GHG) emissions scenarios of the energy system were generated using the bottom-up, optimization model TIMES_PT, assuming the continuation of the 2020 climate policy in the Off-Track scenario, and a reduction of 90% of GHG emissions by 2050 compared with 2005 values, for the other scenarios. This target corresponds to the maximum feasible reduction of GHG emissions computed by TIMES_PT without considering negative emissions or a contraction of energy services demand. Novel improvements were made, particularly the linking between

stakeholders' vision with modelling inputs and the inclusion of circular economy strategies, such as household's equipment and car sharing options. For waste, agriculture and forestry, GHG emissions were estimated based on specific scenarios' drivers (e.g., evolution of agriculture productivity, afforestation area, recycling rate) and tools (e.g., FOD model for CH_4 decay in landfills).

4. Public consultation of the pathways up to 2050, in which stakeholders, including civil society, were able to express their views on modelling assumptions, constraints, and expectations, both online and during dedicated seminars. More than 80 inputs were received.

5. Assessment of uncertain aspects raised during public consultation, through the reformulation of modelling assumptions and the construction of multiple alternative scenarios. Examples include: assumptions on CE (e.g., forest productivity and use of biomaterials; shared mobility and freight load factors; use of secondary materials in industry), the relevance of carbon capture and storage, hydrogen, electricity imports/exports, forest fires, animal protein-based diet, among other. For the core Pack and Yellow Jersey scenarios, the hybrid computable general equilibrium GEM-E3_PT was used to access the economic impacts of carbon neutrality, assuming a soft-link approach with TIMES_PT and sustained by the projected energy system transformation and investment needs.

At the end, more than 65 scenarios were generated for Portugal up to 2050. Carbon neutrality can be achieved until the middle of the century, through feasible cost-effective technologies and plausible investments. All sectors of the economy contribute to emissions reductions, although at different pace over time. Energy supply and transports are the main contributors to decarbonisation, contrary to agriculture and industry, the latter due to process emissions. Energy intensity reduces more than 55% up to 2050 face to today, driven mostly by the significant efficiency of electric and shared mobility, causing also a severe decline of NOX emissions (more than 95%) and allowing to fulfil air emission targets. Power sector is sustained by renewables (mostly solar PV and wind onshore), representing 80% and 100% of electricity production in 2030 and 2050, respectively. Electrification of economy is a key decarbonization pillar, increasing from 26% nowadays to more than 66% by 2050 (% of electricity in final energy consumption), with important impact in energy dependence and the decrease of fuel imports (900 M€/year in average between 2030-2050, a quarter of today's values). CE associated to waste management and to precision, organic and conservation agriculture, likely declines waste and agriculture emissions up to 70% and 37%, respectively. Likewise, the reduction of livestock is a significant decarbonization vector. Forest fires should be kept below 70 000 ha/year (vis-à-vis the average 131 000 ha/year of the last 10 years), to preserve the sequestration ability of the forest, otherwise neutrality will be hard to achieve. Although limited, it is estimated a positive impact on economy (0.9% of GDP), stimulated by up to 7% growth of investment compared with a non-neutrality pathway.

These outcomes led to the approval of a Ministries Resolution. Besides reaffirming the political commitment with the carbon neutrality goal for Portugal, decarbonization targets for 2030 (around 50% reduction face to 2005), and 2040 (around 70%) were also settled.

System dynamics modelling as strategic vision for transforming adult social care in Northern Ireland: from primary research to procurement

Wylie S., Strategic Investment Board
Martin J.,Department of Health, Northern Ireland

Policy Area & Background

The Department of Health (DoH) in Northern Ireland is currently taking forward a process to reform adult care and support as part of a former Minister's ten year vision Health and Wellbeing 2026: Delivering Together. Adult social care describes the suite of activities that enable people with limitations to live independently, for example, help with washing, with dressing or with eating. This is an issue faced by most European nations because a frail and aging population presents a troublesome demographic in terms of who cares for whom, when, in which homes, under what terms, and through which sort of economic or social contracts. Unusually, health and social care are integrated in Northern Ireland, unlike the rest of the UK where they form separate programs and budgets.

System dynamics (SD) modelling has been employed by DoH since 2016 to support the translation of various ideas into empirically-supported policy recommendations. For example, in 2017 an expert panel working for DoH published Power to People — 16 proposals for 'rebooting' the system. These 16 proposals for reform were wide-ranging and ambitious, from ideas about valuing the workforce to notions of forming a social concordant, a society-wide agreement on value and risk. System dynamics modelling has helped to create an operational understanding of how these proposals might link up synergistically.

Design

The suite of system dynamics models evaluate the dynamics between (i) prevalence, (ii) workforce, and (iii) capital estate for the system as a whole, while also delving into digital twin representations of certain services such as domiciliary care services and learning disability services. The modelling effort also includes areas outside of health and social care which drive the dynamics, for example, economic inactivity, trends in technology, trends in home ownership, etc.

In the case of learning disability services — on the back of an institutional crises in various specialist hospitals revealed by the news media — people with a learning disability have worked directly to shape the models, setting new best practice for coproduction with service users. The models have been designed so that people with a learning disability can understand the implications and interact with scenarios. Coproduction is mandated for the design of all health and social care services in Northern Ireland, and SD modelling is providing a pathway to authentically achieving this.

Results

System dynamics modelling has created a dynamic empirical picture of the stresses in adult social care system in Northern Ireland, many of which are driven by broad stroke demographic drivers including an aging population, reduced working age population, longer lifespans with more complicated comorbidities (e.g. learning disabilities with dementia), the dynamics of aging carers, and family pressures on young carers. Through the modeling, these demographic trends are seen to be coupled with social trends such as changes to the structure of communities and to mediums of social engagement, as well as economic trends, such as how young people reside longer with their parents than previously (boomerang generation), changes to the distribution of wealth and cycles of indebtedness, consumer choices and the changing costs of different goods and services, and the local elasticity of labour.

The modelling has shown how demographic, social, and economic trends place stress on the current system of social care by presenting it with population-level conditions which are different from the conditions in which it originally formed. The modelling has also revealed how these demographics, while stressing the old system, hold new energies and opportunities.

Moreover, through the SD modelling, some of the stresses in the system have been revealed to be an endogenous product of the system structure itself, for example, a health and social care system unable to help itself from delivering greater intensity of treatment (traumas etc.) at the cost of preventative activities; a system which can't keep pace with itself in terms of recruitment to fill vacancies (endogeneity of attrition rates and churn). A system which, in its response to rising medical crises tightens thresholds and creates even more crises. A blameless ‘race to the bottom’ in procurement and contracting.

Outcomes

At a policy level, system dynamics has identified leverage points for change, reasons for policy resistance, and potential unintended consequences. This is informing a strategic plan to be published for public consultation in Autumn 2019.

The digital twin modelling of services — at both an individual provider as well as at a market level — has highlighted a need to pilot new procurement structures and techniques to overcome certain endogenous problems. To change what decisions are made within a system doesn’t necessarily require anything from procurement except enacting of past, established processes around new parameters. To transform a system — to change the paradigm out of which the system arises — requires changes to procurement decision-rules themselves. A new procurement framework represents a new set of relationships for an industry, a different pattern of dance emerging between all actors in the system — administrators, professional staff, businesses, service users, regulators, etc. In this instance, the simulation model acts as a layer of insurance enabling government to take innovation risk. Additionally, there have been indications that a whole-system analysis via a can help to make a compelling case for attracting innovation financing. In turn, and analysis of the market has revealed leverage points for policy and regulatory intervention at multiple levels.

Contribution

This work contributes to learning for the modelling community by giving a worked example of embedding system dynamics modelling from primary service design research with service users, to frontline operational understanding of service delivery, through to procurement, commissioning, and finally linked into policy decisions including the leveraging of regulatory and legislative drivers.

Format of talk

It is likely but not confirmed that policy colleagues would attend and speak to the extent that system dynamics modelling has informed the policy direction for the reform of adult social care. It is entirely possible for the audience to run simulations via a model embedded in a web application on their smartphones or computers during the talk.

The use of models to support the design and implementation of the EU Cohesion Policy

Monfort P., European Commission, Directorate-General for Regional and Urban Policy

The EU cohesion policy is the EU’s main investment policy. Its objective is to foster a balanced development in Europe and reduce disparities across EU regions and citizens by co-financing investment projects in different sectors of the economy. In order to reach these goals and address the diverse development needs in the EU MS and regions, more than €350 billion — almost a third of the total EU budget — has been allocated for cohesion policy for the programming period 2014–2020. This makes cohesion policy the second most important EU policy in budgetary terms behind the Common Agricultural Policy.

Assessing impact of cohesion policy is therefore critical and it is one of the most evaluated EU policy. However, at the macroeconomic level this task is far from trivial. Cohesion policy affects a wide range of macroeconomic variables, such as GDP, employment, productivity but also consumption, investment, the fiscal balance and the trade balance. Cohesion policy interventions have direct and indirect effects. For instance, projects in the field of transport directly boost demand in the short run (e.g. public consumption) and they also improve the factors productivity in the longer run (e.g. through an increase in the stock of public infrastructure), which should have a positive impact on GDP. At the same time, these interventions increase labour demand which lead to higher wages and hence prices. This indirect inflationary effect negatively affects GDP.

In addition, the economic performance of the MS and their regions is driven by a wide range of other (EU or national) policy actions as well by many different developments affecting the world economy. These coincide with cohesion policy interventions and the specific impact of the latter can therefore not be identified by simply looking at the data contained in the national accounts. In order to fully capture the general equilibrium effects attributable to the policy and properly assess its impact, a counterfactual is needed which generally requires the use of macroeconomic models at these instruments are among the few to encompass all the channels through which the policy affects the EU regions' economies. Models also offer the possibility to validly compare the outcome of different policy scenario which makes them very valuable for policy design.

The Commission has always relied on formal instruments to assess the relevance and effectiveness of the policy, notably macroeconomic models. HERMIN and EcoMod were used in the past by the Directorate General for Regional and Urban Policy of the European Commission (DG REGIO) to assess the impact of cohesion policy programmes. More recently, the Commission resorted to QUEST for conducting impact assessment of the policy. Other institutions have also used models to analyse the effectiveness of cohesion policy, like the IMF which used its multi-region GIMF (Global Integrated Monetary and Fiscal) model to assess the impact of the EU cohesion transfer in the new Member States from 2004 to 2015.

However, these models produce their results at the national level and this makes them blind on several important aspects of cohesion policy. First, for a large part the EU cohesion policy is a 'spatially targeted' policy, notably for the interventions supported by the European Regional Development Fund (ERDF). Interventions supported by the European Social Fund (ESF) and the Cohesion Fund (CF) are also geographically distributed according to needs that often reflect more the local than the national context. This implies that both the intensity of aid and the policy mix, i.e. the priorities supported by the interventions, strongly vary from one region to another, even within the same Member State.

Second, the impact of the policy depends on the economic and social environment in which it is applied. Most Member States present wide regional variations on many aspects that can potentially affect the impact of the interventions and it is therefore relevant to account for regional idiosyncrasies when analysing the impact of the policy.

Third, some mechanisms which need to be taken into account when assessing the impact of cohesion policy are more likely to play at a regional than at a national level. This is for instance the case with spatial spill-overs through which the programmes implemented in a given region also have an impact in other regions, especially those that are neighbours by geography. Interventions can also possibly change the balance between agglomeration and dispersion forces, thereby affecting the spatial distribution of people and economic activity throughout EU territories. Even though cohesion policy could possibly affect the spatial equilibrium at the level of the EU Member States, its impact on the location of economic activity is more likely to be significant at the regional level.

The analysis of cohesion policy provided by national models can legitimately be complemented by one conducted at the regional level and this is the main reason why the Commission decide to enlarge its analytical arsenal with RHOMOLO, a dynamic and spatial computable general equilibrium model developed jointly by the DG REGIO and the Joint Research Centre of the European Commission. The model simulates the impact of policy interventions on the economies of 267 EU NUTS-2 regions, taking into account the spatial spill-overs that are most relevant for the policy. The model heavily borrows from New Economic Geography and endogenizes the distribution of economic activity across the regions concerned, therefore allowing to capture the impact of the policy on the spatial organization of economic activities in the EU.

The objective of this presentation is to explain the value added of the RHOMOLO model for the analysis of the EU cohesion policy and to provide different examples illustrating how it has been used in the context of impact assessment or evaluation of the policy and how it complements the information retrieved by national models.

Measuring and explaining the EU's Effect on national climate performance

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Sprinz D. F., Detlef Sprinz, PIK - Potsdam Institute for Climate Impact Research & University of Potsdam.

To what extent has the European Union (EU) had a benign or retarding effect on what its member states would have undertaken in the absence of EU climate policies during 2008–2012? A measurement tool for the EU policy's effect is developed. The EU's policy effectiveness vis-à-vis its member states is explained by the EU's non-compliance mechanism, the degree of usage of the Kyoto flexible mechanisms, and national pre-Kyoto emission reduction goals. Time-series cross-sectional analyses show that the EU's non-compliance mechanism has no effect, while the ex-ante plans for using Kyoto flexible mechanisms and/or the ambitious pre-Kyoto emission reduction targets allow member states to escape constraints imposed by EU climate policy.

We have pursued two aims. First, we derived a measurement method for the effect of the EU climate regime on the EU-14 members during the first compliance period of the Kyoto Protocol. Second, we explained the variation therein by focusing on three core political variables, namely the EU non-compliance procedure, the use of the Kyoto (flexible) mechanisms, and national pre-Kyoto emission reduction targets. Our findings show that the EU non-compliance mechanism, on average, does not explain the variation in EU effectiveness, thereby rejecting hypothesis 1. By contrast, our analysis reveals that more ambitious positioning on the use of the Kyoto flexible mechanism and higher pre-Kyoto emission reduction targets reduce the EU's effectiveness, hence supporting hypotheses 2 and 3.

Elevated use of flexible mechanisms and early national positioning to reduce emissions allow these countries to escape pressure from the outside. In policy terms, this implies polarization: those countries that are willing to buy emission-reduction services abroad rather than undertake domestic emission reduction policies, as well as those who embark early on ambitious, unilateral emission reductions, escape the pressure of the EU climate regime. The EU's non-compliance mechanism appears to be an ineffective policy instrument. We should, however, keep in mind that the reported effect is an average effect across countries and time.

The findings beg the question whether the EU is always a benign force in environmental policy. On average, the positive effectiveness score demonstrates that the EU climate regime has a benign effect across the EU-14, but the EU cannot rely on the policy lever under its sole control: the EU non-compliance mechanism.

Instead, our results demonstrate that countries that are willing to use their wealth and wish to advance their climate policies largely remain unaffected by supranational institutions. They 'buy' freedom. Conversely, those who do not wish to lead, at least among our sample of countries within the supranational EU setting, are subject to pressures from the EU. Countries remain 'interdependent, yet sovereign' (Putnam 1988, p. 434) as the EU institutions can only exert pressure on those countries that lack the resources to buy greenhouse gas certificated abroad and/or are laggards in terms of the depth of their national commitments. As our results are broadly robust across specifications and methods used, the fine point emerges that it may partially be in member states' own hands to define whether and to what extent the EU's climate change policy accelerates or retards their national environmental policy performance.

While the EU is formally a supranational institution with uniform powers vis-a-vis its member states, our results indicate that the EU's institutions systematically affects member countries in unequal ways. Nudging the moderates and laggards to increase their environmental ambitions might work, but pushing ambitious members states might well be beyond the capacity of the EU.

The importance of modelling purpose for policy

Edmonds B., Centre for Policy Modelling, Manchester Metropolitan University Business School

There are many sources of confusion between policy actors and modellers, but one of the most common is when there is a lack of precision about the purpose of a simulation. In particular, this is a problem if the policy actor thinks a model will do one thing, but the analyst intends another. For example, the policy actor might think that a model might predict the result of a policy, whilst the analysts are only claiming that they will explore the consequences of some modelling assumptions.

Unfortunately, there is a lot of vagueness from analysts concerning what their models can be justified for. A categorisation of some model purposes is suggested into: prediction, explanation, illustration, analogy, theoretical exploration, risk analysis and social reflection (Edmonds et al. 2019). Each of these is described and illustrated with a policy example, along with the key risks that attend each purpose — how each kind of project might go wrong — and some measures to mitigate against those risks. The model purpose affects many aspects of model development, checking and use.

- **Prediction** is where currently unknown aspects are revealed by use of a model. This is often claimed or implied by policy models, but rarely realised. Predictive ability should only be claimed when there is a track-record of successful prediction before what is predicted is known. Simply fitting known data well is not prediction.

- **Explanation** is when known data is fitted by the outcomes of a model as a result of the structures, processes and setting of that model. This supports an explanation, even when the processes are too complex to check mentally. Such explanations inform our understanding of phenomena in an empirical manner.

- **Illustration** is when a few examples of a process is shown clearly by a model. It does not show how general this is or show any strong empirical connection with what is being modelled. However, it can be informative as to how we think about things, e.g. as a counter example of widely held assumptions.

- **Analogy** is when a model provides a way of thinking about some phenomena, but no stronger empirical relationship is established. This can give insights but can not be relied upon in any way.

- **Theoretical Exploration** is when a model is used to extensively map out the consequences of some assumptions in a general fashion, but it does not claim to say anything about anything observed.

- **Risk Analysis** is when a model is used to reveal and assess processes that might result from an situation or policy, that otherwise might be missed. This does not predict, but does help policy actors anticipate what might go wrong in the application of policy or indicate the appropriate monitoring measures.

- **Social Reflection** is when a model is used to reflect the viewpoints of a set of stakeholders. This can be used to animate the results of these viewpoints and aid discussion and negotiation between them. It is limited by the knowledge of those stakeholders and is not necessarily objectively true in any sense.

Some examples where confusion about model purpose has undermined their policy application is discussed. It is proposed that this categorisation can be the beginning of a set of check-lists that could aid the communication between policy actors and analysts, forming the basis of more well-founded policy modelling projects, and hence inform policy in a more reliable and directed manner (Government Office for Science 2018, Muffy et al. 2018).

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Parallel sessions 4

Modelling support for EU policy design: the EU's Long Term Strategy for climate

Room 0.C
27 November
11:00 – 12:30

Developing a global context for regional 1.5°C scenarios

Keramidas K., Tchung-Ming S., Diaz-Vazquez A., Després J., Schmitz A., European Commission, Joint Research Centre

The global partial equilibrium simulation model POLES-JRC (Prospective Outlook on Long-term Energy System) models has been used for more than two decades by the European Commission as an analytical tool for providing energy and greenhouse gas (GHG) emissions scenarios to inform the climate and energy policy trade-offs for climate mitigation and sustainable energy development at both world and EU levels.

The model's main features include a full description of the energy sector, international energy markets, accounting for energy and non-energy related emissions of GHGs as well as air pollutants, and a global coverage while keeping regional detail for 66 regions. POLES-JRC simulates technology dynamics and follows the discrete choice modelling paradigm in the decision-making process. It determines market shares (portfolio approach) of competing options (technologies, fuels) based on their relative cost and performance while also capturing non-cost elements like preferences or policy choices.

On 28 November 2018, the Commission presented the EU's strategic long-term strategy (LTS) 'A clean planet for all' (EC, 2018) for a climate-neutral economy by 2050 in line with the Paris Agreement. Following the invitations by the European Parliament and the European Council, the strategy covers nearly all EU policies and outlines a vision of the deep economic and societal transformations required, engaging all sectors of the economy and society, to achieve the transition to zero GHG emissions in the EU by 2050. The quantitative backbone of the LTS is based on an integrated modeling framework covering in detail all sectors of the economy across several research institutions. The POLES-JRC analytical framework was used to analyse global transition pathways to a low GHG emissions economy, in order to minimise irreversible climate damages, and providing the global context within which the EU pathways for the LTS were developed.

Reaching the UNFCCC Paris Agreement goal to limit global warming to well below 2°C above pre-industrial levels and aim for 1.5°C requires action from all world countries and in all economic sectors. Global net GHG emissions would have to drop to zero by around 2065 to limit temperature increase to 1.5°C above pre-industrial levels (compared to around 2080 for the 2°C limit). The analysis shows that this ambitious low-carbon transition can be achieved with robust economic growth, implying small mitigation costs. Results furthermore highlight that the combination of climate and air policies can contribute to improving air quality across the globe, thus enabling progress on the UN Sustainable Development Goals for climate action, clean energy and good health.

The global energy system and energy consumption patterns would have to undergo a profound and immediate transformation to sustain unprecedented levels of global annual decarbonisation rates, between 6.1 and 9.0%/year over 2015–2050, compared to 1.9%/year over 1990–2016. In particular, a strong climate objective of 1.5°C would require massive mitigation efforts in the 2020–2040 decades.

This transition is based on three main levers, all of them requiring immediate and strong action: (i) a substantial, cross-sectoral increase in energy efficiency by decoupling economic growth from energy consumption; (ii) a strong shift of energy carriers towards electricity; and (iii) a deep decarbonisation of the energy system. Key mitigation options over 2015–2050 include the increase of the use of renewable energy sources , reduction of non-CO_2 emissions, improved energy efficiency, electrification in final energy demand and land use. Total energy-supply-related expenditure needs would remain similar across scenarios, but the composition changes more towards power sector investments. More expenditure would be needed for investment in infrastructure, especially in the power sector and for demand-side energy efficient investments, while operational costs would drop, following the declining trend of fossil fuels consumption.

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Modelling carbon neutral energy systems

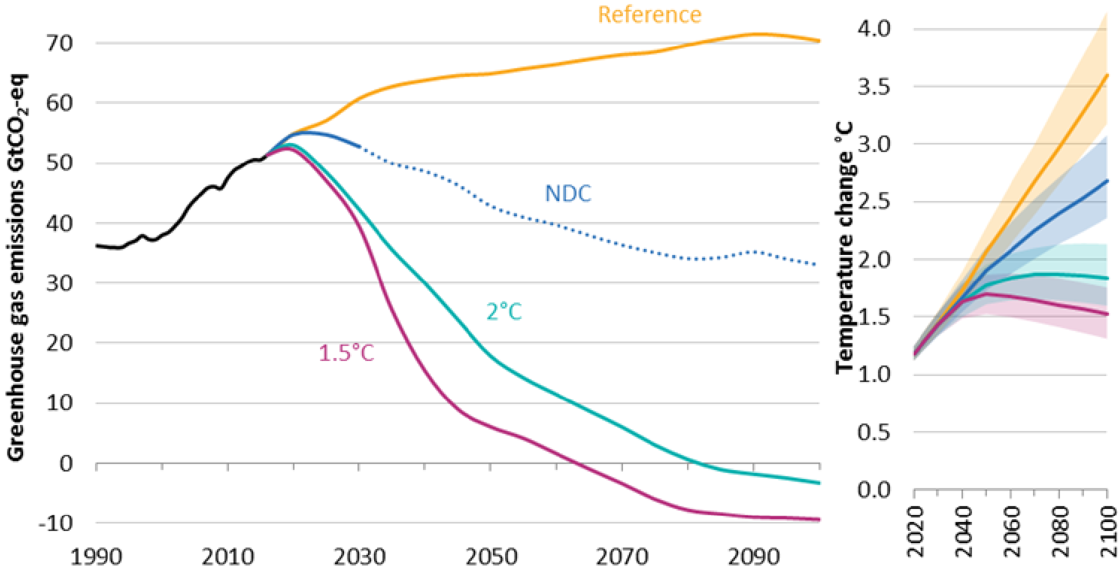
Zazias G., Evangelopoulou S., Fotiou T., Kannavou M., Siskos P., Moysoglou Y., Statharas S., De Vita A., Capros P., E3MLab, National Technical University of Athens

The 2015 Paris Agreement has invited all parties to submit, by 2020, mid-century strategies compatible with the goal of containing the rise in average global temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit it to 1.5oC. The European Commission communicated in November 2018 a long-term strategy towards near-zero greenhouse gas emissions by 2050 and beyond 'A clean planet for all' (EC, 2018). The communication uses several alternative quantitative projections of the EU energy system until 2070, with emphasis on the year 2050. The PRIMES model, developed and operated by E3MLab, was employed to quantify the alternative pathways for the energy system and assess the impacts on energy indicators, investments and costs. The alternative pathways target energy and process emission reductions between 84% and almost 100% by 2050 (compared to 1990); including non-CO2 emissions (but excluding LULUCF) this implies scenarios between -80% and -95% in 2050.

The pathways analysed share the same view that energy efficiency and renewables are the main pillars of the EU strategy towards decarbonisation. However, the dominating energy carrier in the final energy demand sectors varies across the pathways, with electricity, biofuels, hydrogen or synthetic carbon-neutral hydrocarbons being candidates. The conception of the pathways emphasises sectorial integration, such as power and mobility, power and heat, CO_2 capture and re-use in industry, biomass cultivation and advanced biofuels in mobility, power and production of hydrogen and synthetic hydrocarbons. The dominance of an energy carrier implies high industrial maturity levels and learning-by-doing cost reductions for the technologies associated with its production and use. Data supporting the estimation of learning-by-doing potentials for each key technology have been derived after a consultation with industry stakeholders.

The PRIMES energy system model represents all demand and supply sectors in separate modules. The model formulates a typically nonlinear and intertemporal optimisation model for each sector, as a typical decision problem formulated structurally following microeconomic theory. The formulation by sector embeds engineering details of technologies and technical restrictions in the economic behavioural problem. The algorithms solve a mathematical optimisation programme for some modules and a mixed nonlinear complementarity problem for others. Thus, the model derives energy consumption, energy supply and investment

Figure 1. Global GHG emissions and global average temperature change (with median probability)



Note: The NDC scenario assumes that the global average rate of decarbonisation implied by the NDCs in 2020–2030 is maintained over 2030–2050. Source: POLES-JRC 2018; MAGICC online.

depending on prices derived from other modules. The pricing modules calculate supply costs by sector and determine prices by sector of product use based on marginal costs and an allocation of fixed and capital costs depending on assumptions about market conditions. A market balancing routine ensures demand and supply equilibrium in all markets simultaneously, and determines market clearing prices, after iterations with all modules. The model includes an endogenous mechanism for EU-ETS carbon prices and represents many policy instruments e.g. taxes, subsidies, measures removing barriers, infrastructure investment, technology standards, emission or efficiency performing standards, policy targets and others. The model supports impact assessment of policies by comparing a policy scenario to a baseline. The results provide projections of the energy system, investment, prices, costs and emissions until 2070 for each European country.

Several model enhancements were introduced in order to inform the Long-term strategy in particular in relation to the treatment of new fuels. The model enhancements were introduced in both demand and supply modules. An overview of the main enhancements includes:

- An extension of the industrial energy demand module to include direct use hydrogen directly in high-temperature applications, (e.g. iron and steel for direct reduction of iron ore), in furnaces and in the chemical industry as a fuel and as a feedstock to synthesise petrochemicals together with captured CO_2.
- A new module represents the production of hydrogen, direct air capture of carbon (DAC) and production of carbon neutral hydrocarbons, as well as distribution of hydrogen either independently or injected in the gas distribution system. The module calculates feedstock inputs to production of synthetic fuels, choice of technologies (among electrolysers and production routes for synthetic fuels), learning-by-doing, prices of the outputs and distribution costs. In this way the module determines the prices of the synthetic fuels by consumption sector. Blending in the gas distribution is also included in the model
- The power sector model was extended to add the representation of chemical storage of electricity and the modelling of synchronous operation of power generation, load, renewable resources,

storage of the chemical storage inputs and the charging and discharging of the various storage systems. Investment in storage systems including choice of volume and the choice of technology mix is endogenous depending on costs of storage, the prices of the storage inputs and, the marginal costs of the power systems that depend on the availability of renewable resources and the demand by end-users for hydrogen and synthetic fuels. The power sector model solves the interconnected system of all European countries simultaneously, and captures the sharing of balancing resources.

- A module takes care to balance the capturing of carbon dioxide through several ways, competing against each other (DAC, biomass, combustion, industrial processes) and the use of carbon dioxide as a feedstock for synthetic fuels and its sequestration in materials (e.g. feedstock for chemical substances) and in underground caverns.
- Finally, the calculation of overall costs and various policy indicators has been extended to include investment and costs related to hydrogen and the synthetic fuels.

The quantitative analysis undertaken via the model confirmed that the decarbonisation of the EU economy by mid-century is viable both technically and economically, regardless of the ambition level (limit temperature increase to well below 2°C or 1.5°C compared to pre-industrial levels); the pursuit of a carbon-neutral EU economy by 2050 is a plausible target. Some of the technologies included in the analysis are at low or medium technology readiness levels (TRL), however the number of the pathways assessed indicates that the energy system has a plethora of innovative options available, none of which can be considered irreplaceable besides some no-regret ones. The analysis should be complemented in the future with further exercises regarding both technological and strategic aspects around key issues, such as the origin of hydrogen, the origin of carbon molecules for feedstock purposes, the organization of energy markets incorporating very high levels of (variable) RES and competition of resources for energy storage and production of neutral-neutral fuels.

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Costs and potentials for reducing non-CO_2 gases

Höglund-Isaksson L., Winiwarter W., Purohit P., International Institute for Applied Systems Analysis (IIASA)

On 28 November 2018, the Commission presented the EU's strategic long-term strategy (LTS) 'A clean planet for all' (EC, 2018) for a climate-neutral economy by 2050 in line with the Paris Agreement. Following the invitations by the European Parliament and the European Council, the strategy covers nearly all EU policies and outlines a vision of the deep economic and societal transformations required, engaging all sectors of the economy and society, to achieve the transition to zero GHG emissions in the EU by 2050. The quantitative backbone of the LTS is based on an integrated modeling framework covering in detail all sectors of the economy across several research institutions.

IIASA's Air Quality and Greenhouse gases (AIR) program develops and uses the GAINS model framework to produce detailed and internally consistent analyses of abatement potentials and associated costs for air pollutants and the non-CO_2 greenhouse gases methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (HFCs, PFCs, SF_6 and NF_3). Starting in 2008, the program has every 2-3 years provided scientific insights on non-CO2 emissions, future abatement potentials and costs to various climate policy processes in the EU, including the 2020 climate and energy package (EC, 2009), the 2030 climate and energy framework (EC, 2013; EC, 2016), and EU's recent LTS (EC, 2011; EC, 2018).

GAINS uses a linear model approach with emissions estimated by multiplying activity levels with average emission factors for given technology structures applied in a given source sector and year. The strength of the GAINS model lies in its high resolution in terms of emission source sectors and technical solutions to reduce emissions. The GAINS model covers all source sectors for non-CO_2 greenhouse gases, i.e., agriculture, energy production and consumption, industry, solid waste and wastewater management, and fluorinated gases from air conditioning and refrigeration as well as other minor sources. The model relies on externally produced activity projections for the energy and agricultural sectors. For contributions to EU's climate policy processes, macroeconomic and energy activity scenarios are imported from the PRIMES model and agricultural activity scenarios from the CAPRI model. In consistency with macroeconomic projections of the PRIMES model, projections for solid waste generation and consumption of F-gases are produced within the GAINS model. Feedbacks such as limitations on supply of organic waste and animal manure as feedstock for production of renewable energy are exchanged between the GAINS and PRIMES models. Source and country specific emission factors are derived within the model from a wide range of factors identified as influencing emissions and provided enough country specific information is available. This ensures a high level of consistency in emission factors across countries for similar physical and technological circumstances. For each source sector a number of emission abatement options are identified, each with a unique relative removal efficiency and unit cost. The latter is derived from a set of cost parameters that can be both technology specific (e.g., fixed investment cost, non-labour operation and maintenance cost) and country- and year- specific (e.g., labour costs, electricity and gas prices). Effects on removal efficiency and abatement costs from future technological development are captured by dividing abatement technologies into two broad categories; mature technologies and emerging technologies with the latter being technologies described in literature but with limited current application, and attaching different rates of development to the two categories. The GAINS model assumptions for estimation of non-CO_2 greenhouse gas emissions in the EU and technical mitigation potentials and costs have been repeatedly reviewed in bilateral consultations with member state experts and in workshops with sector and technology experts. All assumptions are thoroughly documented in a comprehensive methodology report (Höglund-Isaksson et al., 2018) which is publicly available. Finally, the quality of the scientific basis of the work is demonstrated by the GAINS non-CO_2 team's frequent publications in peer reviewed scientific journals (e.g. Höglund-Isaksson, 2012; 2017; Winiwarter et al., 2018; Purohit and Höglund-Isaksson, 2017; Höglund-Isaksson et al., 2017).

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The land use sector as key to offset residual emissions by 2050

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The Global Biosphere Management Model (GLOBIOM) is a global recursive dynamic partial equilibrium model of the forest and agricultural sectors that is being developed at IIASA's Ecosystem Services and Management Program. The model covers most important crops (>27 crops, four vegetable oil types and related by-products), livestock, and forest products (different types of stem wood, primary forestry residues from wood harvest, industrial residues) as well as biomass feedstocks globally and for the EU. The model is based on a bottom-up approach where the supply side of the model is built-up from the bottom (land cover, land use, management systems) to the top (production/markets). The agricultural and forest productivity is represented at the spatially explicit level through link to biophysical models (crop models, forest growth models etc.) for different production systems. The model computes market equilibrium for agricultural and forest products by allocating land use among production activities to maximize the sum of producer and consumer surplus, subject to resource, technological, demand, and policy constraints. Demand and international trade are represented 58 world regions calibrated to 2000. The model allows for a full account of all agriculture and forestry GHG sources and is linked to the detailed G4M forest sector model. The Global Forest Model (G4M) estimates the impact of forestry activities (afforestation, deforestation, residue harvest, and forest management) on biomass and carbon stocks. By comparing the income of managed forest (difference of wood price and harvesting costs, income by storing carbon in forests) with income by alternative land use on the same place, a decision of afforestation or deforestation is made. As G4M is spatially explicit (currently on a 0.5° x 0.5° resolution), different levels of deforestation pressure at the forest frontier can be handled. The land transitions in G4M are harmonized with GLOBIOM agriculture land demand and includes deforestation driven by the expansion of agricultural areas. G4M simulates forest management aimed at sustainable production of wood demanded by GLOBIOM on a regional scale. As outputs, G4M produces estimates of forest area change, carbon sequestration and emissions in forests, impacts of carbon incentives (e.g. avoided deforestation) and supply of biomass for bio-energy and timber. The models are regularly used EU's assessment modelling framework to provide global and regional agricultural and forestry market outlooks, contribute the land use projections for the EU Reference scenario (EC, 2013; EC, 2016) and to inform EU climate policies on land use related issues (EC, 2011; EC, 2014; EC, 2016).

GLOBIOM/G4M provided the land use mitigation pathways and costs for emissions from the LULUCF sector in the EU's LTS on climate change mitigation 'A Clean Planet for All' (EC, 2018). The models were used to assess various options as to how the land use sector could contribute to achieving the EU's zero GHG target. Implications of different levels of bioenergy demand, feedstock mixes, and lifestyle changes were assessed across 9 scenarios that differed in their level of ambition for emission reduction.

Results showed that the LULUCF sector is able to maintain and even enhance the current carbon sink of around 320 $MtCO_2$ until 2050 if sensible management activities, mitigation policies and lifestyle changes were realized despite the need to increase biomass supply for energy production. Hence, the LULUCF sector is key to achieving the climate neutrality target, as it allows to offset residual emissions from other sectors such as agriculture. The use of dedicated energy crops instead of stem forest was estimated to limit negative impact on the forest sink and therefore helps to maintain the overall LULUCF sink across scenarios. Moreover, the models showed that even under moderate economic incentives in particular in the forest sector targeting mitigation options such as increased afforestation (20 $MtCO_2$/yr at 50 €/tCO_2), reduced deforestation (10 $MtCO_2$/yr at 50 €/tCO_2), and improved forest management (40 $MtCO_2$/yr at 50 €/tCO_2) could substantially enhance the carbon sink. In addition, the increased use of biomass for construction and related increase in the harvested wood carbon sink, as well as lifestyle changes and reduction in animal product consumption were also identified as important strategies that can contribute to mitigation efforts.

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Socio-economic aspects of EU decarbonisation

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Large scale changes to the energy system and transformation towards a net-zero emission society will lead to effects for the entire economy. The in-depth analysis accompanying the LTS (EC, 2018) therefore takes a detailed look on how decarbonisation pathways affect macroeconomic indicators like GDP, aggregate investment under altered investment requirements, international energy trade (e.g., EU net imports for energy), as well as sectoral output and employment.

JRC-GEM-E3 is a computable general equilibrium (CGE) model that captures economy wide effects and was used to assess a range of macro-economic issues stemming from the analysis of the energy transition. The model captures interactions between different actors (industry, households, government) and captures bilateral trade between 40 regions. The economy is represented by 31 sectors, focussing on energy producing and energy intensive industries.

In JRC-GEM-E3, both the macro-economic baseline as well as the decarbonisation scenarios were constructed using the results of the PRIMES energy system model for the baseline energy scenario for Europe. For the rest of the world, the macro-economic baseline assumes implementation of the Intended Nationally Determined Contributions (INDCs) as reported to the UNFCCC and as modelled by POLES-JRC.

For the emission reduction scenarios, different levels of reduction (80% and reduction in line with a global 1.5C pathway) were assessed. In addition, it was analysed how the results change under different assumptions for climate policies in the rest of the world. Under 'fragmented action', it was assumed that only the EU would implement climate policy, while under 'global action' a coordinated effort towards a decarbonized global economy was followed. The table below shows resulting impacts on EU GDP.

Changes to GDP relative to the baseline also depend on industry behaviour. GDP impacts are slightly lower when industries use freely allocated permits to maximize the market share. When the opportunity cost of the free permits is added to the final price ('profit maximization'), the output of the economy is slightly lower. JRC-GEM-E3 was also used to investigate implications for different sectors of the economy, as the decarbonisation pathways will affect output of various sectors differently. Changes in output are also reflected in shifts in the employment structure. Different scenarios were run with the model with regard to assumptions on the labour market. This includes a labour market in long-term equilibrium where employment is unresponsive to changes in the wage rate and an alternative formulation where lower wages can increase employment. Wages can be lowered when revenues from auctioning carbon permits are used to lower labour taxes.

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Table: Impacts on GDP in different scenarios

GDP vs. Baseline, 2050 JRC-GEM-E3	Fragmented action		Global action	
	80% reduction	1.5°C	80% reduction	1.5° C
Profit maximisation Perfect labour market Lump-sum transfers	-0.13%	-0.63%	-0.28%	-1.30%
Market share maximisation Perfect labour market Lump-sum transfers	-0.10%	-0.59%	-0.25%	-1.26%
Market share maximisation Imperfect labour market revenue recycling	0.05%	-0.29%	-0.18%	-1.09%

Parallel sessions 5

Model quality and transparency 2

Room 0.A
27 November
13:30 – 15:00

Map or compass? Improving model contribution to long-term climate strategy. Insights from 4 country studies

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Parties to the Paris Agreement (PA) are asked to prepare and submit by 2020 the next round of so-called nationally determined contribution (NDC), which define their mitigation (and adaptation) objectives typically for the horizon 2030. Parties are also requested to prepare and submit by 2020 mid-century low greenhouse gas emission development strategies.

Preparing these documents constitutes a challenge for two reasons. First, the PA goal of limiting temperature increase well below 2°C relative to preindustrial level by the end of the century cannot be met by marginal changes in the energy supply sector. Major changes in production and consumption patterns across all economic sectors is required, at very rapid pace. Finding technologically, economically, socially and environmentally plausible pathways to successfully complete these transitions thus requires to assemble and articulate a very large range of expertise that goes beyond any individual sector.

Second, 2030, let alone 2050, is an unusually long time horizon for policy-making, where the 'long term' is typically no farther than a few years ahead. Given uncertainties on future parameters (e.g., availability of mitigation technologies, economic conditions, citizens' preferences, etc.) and lack of legitimacy (and possibility) for current policy-makers to coerce future policy-makers into following their plans make these documents exploratory rather than prescriptive. Yet mid-century strategies tend to start from a mitigation goal at horizon 2050, such as the factor four (a division by four of emissions relative to, e.g., 2010) or carbon neutrality (net remaining GHG emissions compensated by equivalent removals from natural carbon sinks).

Given the complexity of the problem at hand, and given the time horizons involved, it is not surprising that countries often rely on techno-economic models as a support tool for the preparation of their national low-carbon strategies (NDCs and mid-century strategies). Models help provide numerically consistent pictures of the future, with a degree of complexity superior to what the human mind can achieve, and with a degree of consistency that qualitative forms of prospective cannot reach.

If using models in support of policy-making is by no means new, complexity and timing create a specific challenge for model use in the case of climate mitigation. Specifically, as noted above, models must capture an ever expanding range of mitigation options across sectors and across all components of supply and demand. This creates a major tension between the degree of granularity required for the model to dialogue with stakeholders in each sector (energy, transport, housing, but also agriculture, forestry, macroeconomics, etc.), and the risk for models to become too cumbersome or impossible to control.

The objective of this paper is to explore how models currently meet this challenge, and to draw insights on how they might be improved to this regard. The question touches not only the technical structure of individual models, but also the way different models (for example, different sectoral models) exchange with each other, and how models and modelers interact with stakeholders and with policymakers. The policy-making process of which models and modelers are part is thus as important to our study as the technical structure of these tools.

To meet this objective, we rely on four national case studies in which models have been used to support the development of low carbon strategies: France (Second National Low Carbon Strategy (SNBC), 2018), Sweden (Climate Act, 2017), Brazil (NDC, 2015), and the USA (Mid-century Strategy for Deep

Decarbonization, 2016). These case studies are all based on a variety of models to assess national trajectories (e.g. US, Brazil and France) but they differ as to their horizon and as the ways of framing these trajectories. For example, the US scenarios are technology / innovation centered (e.g., carbon sequestration); the Brazil exercise addresses the distributive impact of a set of climate change policies (carbon tax, command and control, early or delayed action); and the French SNBC is geared towards 2050 carbon neutrality, an unprecedented horizon and objective for the country, which challenged methods and ways of interacting with and around models.

Our material is based on a qualitative study combining document analysis and semi-directive interviews (with modelers, independent consultants, public agencies and administrations) undertaken in 2019 (April to July). The comparison of the case studies (chronology, organization, process, outcomes) allows highlighting a set of valuable lessons for the modeling of NDC and low carbon strategies on different scales, horizon, in different settings and with different objectives.

We find that the way these models are used is country specific and dependent upon a range of factors including the habits and practices to use these models by public administrations, the existence of academic or private institutions developing such tools, dedicated fora gathering stakeholders and modelers etc. Analyzing more in depth the functioning of these ecosystems allows for not only capturing the adequacy between the use models and the institutional context, but also envisaging improvements in those fields.

We find that each country also adopted specific modalities of interactions between modelers and stakeholders in the definition of scenarios and their evaluation. For example, Brazil has set a rich participatory process with multiple direct interactions between modelers and stakeholders (representative from business sectors, NGOs, experts etc.). In France the administration set itself with a central, coordinating role, mediating almost all relations with modelers and with stakeholders. And in Sweden, the modeling evaluation is deeply rooted in the political process (parliament).

Ultimately, we find that the type of insights models are tasked to provide to the policy process is critical, especially for the mid-century strategies. There is a tension between the objective of exploring a wide range of plausible futures (the 'map' function of models) and helping to set the right course, especially when short-to medium-term decisions must be taken (the 'compass' function of models).

Modelling climate-energy linkages in national energy and climate plans: achievements and challenges

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Implementing Paris Agreement requires a fast and radical transformation of politics, economy and society. Worldwide emissions of greenhouse gases need to fall to zero by 2100. Pathways limiting global warming to 1.5 °C show that CO_2 emissions need to be reduced to net zero globally around 2050 (IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, 2018).

The European Commission calls for climate neutral Europe by 2050. Implementing such reforms requires energy transition, since energy sector is globally responsible for more than half of emissions. There is still vivid debate as to which extent energy transition is justified and feasible. The political will to make the necessary decisions depends partly on improving the analysis and estimates of the economics of decarbonisation compared to reference scenarios. Then the consequences of unmanaged climate change can be weighed much more transparently against the investments and innovations necessary for decarbonisation.

According to The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2013 and 2014 and Stern (2015) current models tend to underestimate the potential impacts of unmanaged climate change and the benefits of a transition to low-carbon growth, both. Therefore, models that give a more accurate picture and support formulation of more ambitious policies are necessary.

This paper analyses and maps models used in EU member states to formulate policies in integrated national energy and climate plans. Integrated national energy and climate plans define a pathway to 2030 to ensure meeting 2030 targets and a transition to a climate neutral economy that is fair and cost-effective for all. In line with Energy Union Governance Regulation(The Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action), NCEPs cover the five interlinked dimensions of the energy union:

- Security, solidarity and trust
- A fully integrated internal energy market
- Energy efficiency
- Climate action, decarbonising the economy
- Research, innovation and competitiveness — supporting breakthroughs in low-carbon and clean energy technologies

for the period 2021 to 2030 (and every subsequent ten year period).

Drafts NCEPs had to be submitted by end of 2018. The European Commission published assessment of NCEPs and provided specific recommendations addressed to each member state in mid June 2019. The final version of NCEPs should be submitted by the end of 2019.

Each NECEP has to include description of the planned policies and measures necessary to achieve goals of the Energy Union, a general overview of the investment needed to meet the objectives, targets and contributions; an assessment of the impacts of the planned policies and measures to meet the objectives of energy union and a general assessment of the planned policies and measures on competitiveness.

The aim of the paper is to map draft NCEPs based on analytical approach and determine to which extent level of ambitious defined in NCEP depends on the modelling approach. This could serve as a basis for outlining common elements that should be considered in revisions.

The starting hypothesis is that level of ambitious of NCEP depends on the analytical base used for policy development.

In particular, that:

- First, member states that rely primarily on no-regret policy measures and traditional energy planning models (energy supply-demand models, emission reduction models, renewable energy models, forecasting models) define less ambitious goals and targets.
- Second, usage of more sophisticated models (e.g. integrated assessment models, IAMs or third wave models — dynamic stochastic computable equilibrium models, DSCEM or agent based models, ABM), including models that consider disruptive options (relating to change of energy mix and the way energy is used and distributed) enables setting more ambitious targets, primarily in the countries with higher innovation index.

Structure of the paper is as follows:

First, Energy Union Governance Regulation and role of NCEPs are briefly presented. Focus is on the established targets and impact assessment included in the draft NCEPs. Based on available information, data sources used, assumptions and modelling approaches in the EU are categorised.

This is followed by review of the Commission's assessment and recommendations, focusing again on the level of ambition and feasibility of achieving goals. The main factors and how member states have weighted them in defining objectives and policies are identified. It is also examined to which extent policy measures and activities are coherent with expected impacts, and which impact (financial, societal, impacts on competitiveness) are considered as most relevant. This is accompanied with review of interlinkages that are considered (e.g. links among affordability, reliability and sustainability of energy system).

This analysis, together with results of first section, enables mapping NECEPs and testing starting hypotheses.

Third section discusses common issues, challenges and best practices identified by mapping relating to elements that increase quality of analytical basis for policy development. These include data sources and modelling applied. Special attention is given to assumptions related to costing transition, i.e. future evolution of costs and performance of various technologies, discount rates, comparison with reference scenarios (cost of unmitigated climate change and business and usual scenario, costs of reference scenario related to economic growth, cost of locked in infrastructure and ways to tackle disruptive options and costing uncertainties (the feedback loops in the innovation process that interact across the economy, prompting institutional and behavioural change, possible discoveries and economies of scale).

Finally, based on identified elements and approaches to model interrelations between the five dimensions of the energy union, conclusions and recommendations are formulated.

These relate to:

- Models used and identified best practices
- Interdependence of level of ambition and used analytical basis
- Common issues and challenges related to harmonizing approach in future
- Range of expected impacts and interdependencies.

Analysis of current climate and energy policies: are countries on track to meet their NDC targets?

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Short Summary. Under the Paris Agreement, countries committed to a variety of climate actions, including post-2020 greenhouse gas (GHG) emissions reduction targets. This study [1] compares projected GHG emissions in in 25 major emitting countries/regions up to 2030, taking into account the emission trajectories based on current policies and the implementation of nationally determined contributions (NDCs). This study concludes that 16 out of the 25 countries and regions analysed are not on track to achieve the NDC targets they have set for themselves.

Not all countries on track to achieve targets set in NDCs

The degree to which the 25 major emitting countries are likely to achieve their NDC targets under current policies was found to vary. Of those considered in this study, China, Colombia, EU28, India, the Russian Federation, Saudi Arabia, Turkey, and the Ukraine are likely or roughly on track to achieve or even overachieve their self-determined unconditional 2025/2030 targets with currently implemented policies. For Mexico, the achievement of 2030 targets was found to be uncertain with implemented policies. The other 16 countries (Argentina, Australia, Brazil, Canada, Chile, Democratic Republic of the Congo, Ethiopia, Indonesia, Japan, Kazakhstan, Morocco, Republic of Korea, South Africa, Thailand, the Philippines, and the United States), require additional measures to achieve their 2025/2030 targets. It should be noted that a country likely to meet its targets not necessarily is undertaking more stringent action on mitigation than a country that is not on track, as this depends on the ambition level of the nationally determined target, and because countries have different policy-making approaches [2].

Progress on reducing greenhouse gas emissions also varies

Currently implemented policies are projected to influence GHG emissions, but do not prevent emissions from increasing up to 2030 (above 2010 levels). This is the case, not only in developing countries (Argentina, Brazil, China, DRC, Ethiopia, India, Indonesia, Kazakhstan, Morocco, the Philippines, Russia, Saudi Arabia, South Africa, and Thailand) but also in OECD countries (Chile, Mexico, Republic of Korea, and Turkey) up to 2030, compared to 2010 levels. Emissions in the remaining seven countries are projected to remain stable, approximately at current levels, or to decrease further, under current policies. Significant overachievement of NDCs: India, Russian Federation, Turkey and Ukraine. For these countries, the current policies scenario projections for 2030 are more than 10% lower than the unconditional NDC target levels. These countries could revise their NDCs to more ambitious ones under the Paris Agreement's ratcheting mechanism.

Changes since the Paris Agreement was adopted

The study also assessed how countries' current policies scenario projections have changed since 2015, when the Paris Agreement was adopted. The comparison with our 2015 study, which covered thirteen countries, shows only six countries (Australia, Canada, China, EU, Turkey and the United States) show lower emissions projections for 2030; for the remaining seven countries (Brazil, India, Indonesia, Japan, Mexico, Republic of Korea, Russia) the projections were either similar or even higher.

Still more effort needed to stay well below 2 °C

Even if all the countries' targets would be fully met, the combined mitigation impact would fall far short of what is required to limit global warming to well below 2 °C and possibly 1.5 °C — the climate targets set in the Paris Agreement. Previous studies have shown that, even with full implementation of all the plans countries submitted in this agreement, global temperature would rise by 2.6 °C to 3.1 °C, by the end of the century [3].

Methodology

NewClimate Institute, IIASA and PBL have estimated the impact of the most effective current policies on future GHG emissions. The calculations by NewClimate Institute are largely based on its analyses for, and informed by, the Climate Action Tracker project [4], and used existing scenarios from national and international studies (e.g. IEA's World Energy Outlook) as well as their own calculations of the impact of individual policies in different subsectors. PBL calculated the impact of individual policies in different subsectors using the IMAGE integrated assessment model. The starting point for the calculations of the impact of climate policies is the latest SSP2 (no climate policy) baseline. Current climate and energy policies in G20 countries, as identified in the CD-LINKS project, were added to that baseline by changing model input parameters to achieve the policy impacts [5]. Both NewClimate and PBL scenario calculations were supplemented with those on land-use and agricultural policies using IIASA's global land-use model GLOBIOM.

Future research

The number of studies analysing whether countries are on track to achieve their NDC targets is still limited in literature, whereas from a policy perspective it becomes more and more important to look at the implementation of the NDCs [2]. Therefore, it is encouraging that our work is used for the implementation and development of NDC and current policies scenarios for many global and national models in the CD-LINKS project [6, 7] and the upcoming European H2020 ENGAGE projects. This has been done by the development of the modelling protocol for the implementation of current policies in all models. That protocol was based on the work mentioned above, and an iteration with national experts was added, to ensure inclusion of the most recent and most important policies (in terms of emissions).

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How to make social-environmental modelling more useful to support policy?

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Social-environmental systems (SES) are characterized by a tight coupling of human and environmental dynamics (Berkes and Folke, 1998; Folke et al., 2010; Schulze et al., 2017). To support sustainable management of these systems, it is crucial to understand both their social and environmental aspects (Carpenter et al., 2009; Ostrom, 2009; Chapin et al., 2010). Modelling is often proposed as an effective tool to address these interlinked problems and provide sustainable solutions to them as it allows disentangling causes and effects of human behaviour and environmental constraints.

Whereas social-environmental modelling has made many contributions in the scientific realm to provide answers to environmental issues such as sustainable management of natural resources and ecosystem services (Karagiannakos, 1996; Schlüter et al., 2009), land-use/land-cover change (Parker et al., 2003; Schulze et al., 2016), or biodiversity conservation (Myers et al., 2000), the impact of these studies in real world decision-making and policy support has so far been very limited.

In contrast, models from other fields such as transportation planning, epidemiology, or pesticide risk assessment have been integrated into policy-making processes and have successfully been applied to real-world problems.

In this paper, we identify reasons for the limited impact of SES models and discuss steps that need to be taken to increase this impact. By learning from fields where models have already been successfully involved in policy making, we aim to facilitate the integration of social-environmental modelling into practice and to increase its relevance for real-world applications. By impact, we mean that models have contributed to a policy decision in the widest sense, which can range from stimulating a policy process (e.g. raising awareness for so far neglected issues), influencing discussions around a decision (e.g. laying out certain options or scenarios), up to policy decisions being directly based on model results. Impact does not state whether the outcome of the decision was positive or negative from a given perspective.

To address this question, we investigate seven good-practice examples in detail. We identify key aspects that enable or impede the application of such models. The selected studies range from purely ecological problems such as the management of fish populations in rivers (Railsback et al., 2005) or control of animal diseases (Thulke et al., 2018) to coupled SES research such as sustainable fisheries in Australia (Fulton et al., 2014) and water management in Jordan (Klassert et al., 2015). All examples have in common that they did not only deliver scientifically innovative insights but were also used to guide actual policy decisions.

For the evaluation of these examples we use a list of criteria that is inspired by a framework developed in Gray et al. (2018). We follow their approach and assess the models with respect to aspects concerning the purpose of the modelling endeavour, the process of exchange between modellers and policy makers, details on this partnership, and the product that emerges from this exchange, i.e. the range and type of application of the model outcome in practice. We interviewed the authors of those studies about their experience in the entire modelling process. To interpret these achievements, we asked them to self-assess their studies and evaluate their models against the questions in the criteria list, without us adding any additional rating.

While the good practice examples that we examined display a wide range of individual characteristics, several common points concerning transdisciplinarity, data availability and urgency of the modelling process stand out. Soft factors such as prior experiences of the policy makers with modelling, interpersonal trust and communication usually determine the chances of success or failure of a project. Furthermore, we observe that the confidence of policy makers in purely ecological models is higher than in social-environmental ones, where modelling human behaviour is still strongly questioned. In addition, data collection of social data is associated with more effort and more limitations. However, in specific fields such as coastal fishery in Australia, where a long-standing relationship between policy and science already exists, the problem of data availability is smaller. Another aspect that impedes the use of models in policy making is related to the short-term obligations of policy makers, where long-term perspectives are of minor importance.

To summarize these results, we synthesize a list of key principles of success or failure that social-ecological modellers should consider when they aim for real-world impact of their models. In this list, we differentiate between what lies in the scope of action of modellers, of decision makers, or rather beyond. We derive (a) main characteristics needed in models to be suitable for policy analysis, (b) necessary steps for interaction between policy makers and modellers, and (c) ways to overcome the drawbacks and challenges associated with the application of models in policy making.

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Quantitative pest risk assessment — a modelling methodology supporting EU plant health policy

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To support the recent revision of the EU plant health legislation, the European Commission requested the European Food Safety Authority (EFSA) to evaluate the status of several plant pests listed in the Annexes of Council Directive 2000/29/EC. Given the magnitude of the task, a two-phase approach was developed by the EFSA Plant Health Panel (EFSA PLH Panel et al., 2018).

First, a qualitative pest categorisation determines whether the pest fulfils the criteria of a quarantine pest or those of a regulated non-quarantine pest. Following the outcome of the first phase, for selected pests, a quantitative risk assessment is performed. Among other elements, this may include the evaluation of (i) risk reduction options (RROs) and (ii) the effectiveness of current EU phytosanitary requirements. In this way, modelling efforts are focused to those pests for which a full risk assessment was felt to be needed by risk managers.

Quantitative models are likely to better inform pest risk management decisions, as these are often based on comparisons of scenarios, e.g. with or without selected RROs in place. Combining uncertainties deriving from the different estimations becomes straightforward. The approach also makes it possible to objectively identify which variables are more responsible for the uncertainty of the final outcome. This can inform research needs to reduce uncertainties of future assessments.

The new methodology includes a two-tiered approach: depending on risk managers' needs and resources availability, the assessment can be conducted directly, using weight of evidence and quantitative expert judgement (first tier) or applying quantitative models in the various sub-steps of the pest risk assessment(second tier), e.g. pest prevalence at the origin, trade volumes, climate suitability in the EU for the pest, pest dispersal potential, and impacts in the endangered area.

We focus here on the second tier, i.e. the development of quantitative models for assessing pest entry, establishment, spread and impact. The approach has been tested on ten taxa, covering a variety of pathogens and invertebrate pests: the nematodes Ditylenchus destructor and Radopholus similis, the mite Eotetranychus lewisi, the phytoplasma Flavescence dorée, the bacterium Xylella fastidiosa, the insect Spodoptera frugiperda, and the fungi Atropellis spp., Ceratocystis platani, Cryphonectria parasitica and Diaporthe vaccinii. These case studies had sufficient detail to enable the quantification of key processes. However, the assessments were kept as parsimonious as possible to ensure transparency and parameterisation with the available data. The modelling framework is thus adaptable to make the assessment appropriate to the level of detail required.

Examples of a conceptual and formal entry pathway model are provided in the guidance to illustrate the methodology. The pest risk assessment is based on scenarios. A conceptual model describes the system to be assessed, e.g. an entry pathway leading to pest establishment, spread and ultimately impact. For each step and scenario of the model, relevant data are crucial, but often not at hand. Models therefore require expert knowledge to estimate plausible distributions for several parameters. These distributions reflect the uncertainty of experts in a rigorous way. It is important to communicate clearly (e.g. without excessive use of decimals, thus not reflecting the intrinsic uncertainty of model structure and inputs) and in a consistent manner (e.g. by systematically referring to the variation around mean results) the quantitative results from the models. Guidance on both verbal and visual communication of model results is provided.

The results of the pest entry model are reported as the uncertainty distribution of the estimated number of founder pest populations. This assessment is made separately for each entry (sub)pathway and then combined. Establishment is described as the uncertainty distribution of the likely number of founder populations establishing due to entry (e.g. expressed as suitable grid cells in a map), in view of climatic and other environmental factors. Spread is depicted as an uncertainty distribution for the increase in the spatial occupancy of the pest within the risk assessment area. The consequences of pest introduction and spread are conveyed as estimated uncertainty distributions of changes to crop output, yield or quality under different risk management scenarios. Environmental impacts can also be gauged in terms of estimated changes in ecosystem services provisioning and biodiversity levels.

This modelling framework makes it possible to clearly respond to the questions that motivated the pest risk assessment and favours a closer dialogue with risk managers, as they are involved in the definition of the scenarios to be developed so as to obtain fit-for-purpose outputs.

In addition, the outputs of quantitative pest risk assessments are essential for designing pest surveillance strategies both for detection and delimiting surveys. For example, the outputs of models predicting the likelihood of entry can be used for defining relative risks of different locations to survey in a risk-based approach. The outputs of spread models could also help in prioritising the areas to survey. Model outputs are integrated in the EFSA Pest survey cards (see the virtual issue of the EFSA Journal at https://efsa.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1831-4732.toolkit-plant-pest-surveillance), and are thus used for supporting decision making (e.g. key distances for designing delimiting surveys of Xylella fastidiosa).

The advantages of this quantitative approach are also shown by the recent work on EU priority pests (EFSA et al., 2019). Article 6 of the new EU Plant Health Law (Regulation 2016/2031) sets out the requirement to establish a list of priority pests from the list of EU quarantine pests. The prioritization needs to be based on an assessment of the severity of economic, social and environmental impacts that those pests could cause in the EU. The European Commission asked the Commission's Joint Research Centre (JRC) to develop a multi-criteria decision analysis to rank pest species based on their potential impacts and EFSA to support JRC's work by collecting the available evidence for 28 pest species, identified as suitable candidate priority pests, on their potential capacity for establishment, economic and environmental impacts and difficulty of eradication. For each pest, EFSA identified the area of potential distribution in the EU at NUTS2 level and carried out expert knowledge elicitations to obtain quantitative assessments and uncertainty analyses for yield and quality losses, spread rate and time to detection. The elicitations were conducted under two scenarios using assumptions common to all pests, making the results comparable among the pests and translatable by JRC to monetary values. JRC then developed a composite indicator, the Impact Indicator for Priority Pests (I2P2), in order to rank the 28 species according to potential economic, social and environmental impact in the EU and fed it with the values provided by EFSA. The I2P2 proved its general applicability to quarantine plant pests that can potentially affect EU crops and forests.

Based on the experience gained so far, this modelling framework (which is built upon international principles of pest risk assessment) has improved policy support in EU plant health. The main advantages are: (i) flexibility (conceptual and formal models can be set at appropriate levels of sophistication and resolution), (ii) clarity (results can be easily compared among scenarios and for different pests), and (iii) transparency (not only data, but also lack of data, i.e. uncertainties, are built into the model and presented in the results).

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Parallel sessions 5

Scenarios, model linkages and data for policy 3

Room 0.B
27 November
13:30 – 15:00

Strategic sourcing 2.0: improving fiscal efficiency using big data

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Public procurement amounts up to one third of general government expenditure across OECD countries and little over one fifth across Latin American countries (OECD, 2016, 2017). In the face of such an immense spending effort, maintaining and increasing fiscal efficiency in public procurement remains a key challenge for governments across the world. However, so far systematic, real-time, and readily available efficiency measurements as well as explanatory frameworks have been largely lacking, making informed policy making challenging.

With the spread of e-procurement systems around the word (OECD, 2016, 2017), the ready and real-time availability of government-wide, high granularity spending data, typically on the contract or purchased item level, is increasingly available. Such datasets, if of acceptable quality and scope, can potentially provide the much needed efficiency metrics as well as identify cues as to which policy-relevant factors can influence them.

Against this background, this paper introduces a novel and comprehensive framework for identifying potential savings and implementing the necessary policy changes in the procurement of standardized goods and services.

The approach proposed is both narrow and comprehensive. It narrowly focuses on unit prices paid for standardized goods and services for most of the analysis, but also offers a government-wide methodology proposing policy improvements across the board. Conceptually, it combines traditional methods of strategic sourcing with economic theories of auctions and data science. Empirically, it employs mixed methods combining country-wide descriptive and explanatory quantitative models with in-depth case studies of selected markets. In particular, the analytical framework consists of 3 key components which work best together but can also be deployed independently:

1. public procurement market overview, using interactive visualisations;
2. regression modelling of unit prices across government; and
3. in-depth case study analysis of selected large markets such as vehicles.

The analytical framework has been refined through implementation in seven Latin American countries including Brazil, Ecuador, Peru, or Uruguay and further sub-national entities such as the state of Santa Catarina and the city of Rio in Brazil. The below empirical examples are drawn from the authors' analysis of Brazil's federal government given that it is the largest country in our sample.[1]

This article makes a contribution both to the academic literature and policy debates. From an academic perspective, it develops a carefully tested mixed methods methodology for price modelling rooted in established theories and methods but applying them to a new context characterised by data of exceptional scope and depth. While there have been a few specific studies looking at isolated factors using similar data, to the best of our knowledge, our study is the first one to bring this literature together and propose a comprehensive methodology. From a policy perspective, our methodology offers a reliable and specific tool for policy makers to understand public procurement markets and to identify factors driving cost savings, either directly under policy influence (e.g. length of advertising tenders) or indirectly influencible (e.g. number of bids submitted). The methodology feeds into day to day policy making, leading to recommendations typically feasible within existing legal frameworks by tweaking the parameters of policy

1 The empirical analysis extensively draws on, but also goes considerably beyond the authors' prior analysis Brazil's federal government published in (World Bank, 2017, pp. 55–66).

implementation. As the methodology is fully transparent and largely automated, real-time policy advice is feasible as well as simulating the impact of distinct policy scenarios.

As a demonstration of how the model is implemented, our analysis of Brazil's federal government is taken as an example. This is a suitable choice as it is the largest country in our sample. Data-driven price modelling points at 15 % savings the federal government due to improving public procurement processes and decisions, rather than fundamentally reconfiguring what is bought or the regulatory framework. Realistic policy changes such as increasing the length of advertising tenders or wider use of electronic auctions are required to achieving projected savings with each intervention independently priced guiding policy prioritisation. We conclude by discussing the strengths and weaknesses of the approach and what future improvements could be made.

Uses and potential of large-scale, micro level government contracting datasets for policy modelling

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Public procurement plays a crucial role in economic development and the quality of government across the European Union (EU): on average, it amounts to about 13 % of GDP or 29 % of government spending (European Commission, 2016; OECD, 2015). It is a genuinely cross-cutting government function concerning virtually every public body, and is also one of the principal means by which governments can influence growth rates and the quality of public services. However, our understanding of the quality of public procurement processes and outcomes is very much in its infancy, which limits governments' capacity to intervene in pursuance of specific public procurement as well as broader objectives such as public financial management or local economic development.

In pursuance of better understanding and governance of such large portion of government activities, we describe a unique, micro-level, large-scale database of the EU-wide Tenders Electronic Daily (TED) combined with official national public procurement datasets. Such a dataset capture public procurement activities across the whole EU-28 between 2006-2018 on the tender and contract levels. It is publicly available thanks to Horizon 2020 funding of the DIGIWHIST project at opentender.eu. The total dataset contains over 19 million contracts and it is continuously updated using advanced web scraping and parsing technologies.

Among many potential uses of such data, one will be discussed in detail: assessing the quality of institutions at the regional level. In order to enhance prosperity, human well-being and the territorial cohesion of the EU, the quality of governance (or quality of institutions) is a fundamental precondition. High-quality institutions are characterised by 'the absence of corruption, a workable approach to competition and procurement policy, an effective legal environment, and an independent and efficient judicial system', as well as 'strong institutional and administrative capacity, reducing the administrative burden and improving the quality of legislation' (European Commission, 2014, p. 161). Such a broad understanding of institutional quality is also underpinned by influential academic thinking focusing on impartial policy implementation rather than the content of policies or democratic decision-making processes (Rothstein & Teorell, 2008). Building on this focus on policy implementation, good governance in public procurement is assessed according to four main dimensions:

- Transparency (e.g. amount of information published in procurement announcements);
- Competition (e.g. average number of bidders);
- Administrative efficiency (e.g. length of decision-making period); and

- Corruption (e.g. the use of non-open, opaque procedure types).

Each dimension of good governance as well as a composite score are calculated and their validity tested by comparing them to widely used regional indicators such as GDP/capita, European Quality of Government Index (EQI), or public service meritocracy. All tests confirm that the indicators proposed, based on prior academic and policy literature, are valid.

The new indicators enable a detailed analysis of the quality of NUTS 3 and NUTS 2 regional public procurement governance according to the four above-mentioned dimensions, while changes over the last 10 years can also be explored. We find a mixed picture of regional convergence between 2006–2015 in the EU. While some Central and Eastern European regions have converged to the EU average, many Mediterranean regions have strongly diverged and, surprisingly, some well-governed Western and Northern European regions have also experienced a strong deterioration in governance quality. Overall, governance quality and competition in particular have deteriorated across the whole EU.

Using synthetic control methods for policy evaluation: modelling challenges, new data, and evidence from EU carbon markets

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Motivation and summary

Assessing whether a policy works is an enormously difficult task. This assessment is complicated by the fact that whenever a new policy is introduced, changes in the outcome can rarely (if ever) be attributed to the policy alone as many other factors change at the same time. For example, a country's carbon emissions may decrease because of new regulatory policy, but the reduction may equally well stem from lower economic activity. Isolating the **causal** effect of a policy hence requires to know what carbon emissions would have been, had the policy never been introduced, or what causal inference scholars call the counterfactual.

In this paper, we apply the generalized synthetic control method (Xu, 2017) to estimate counterfactual emission paths for European countries regulated under the European Union Emissions Trading System (EU ETS) to assess the effectiveness of EU carbon markets. Importantly, this modelling approach offers a statistical method to 'purge' estimates of the effects of other (confounding) factors, such as the economic crisis or increases in renewable capacity over the same time. Drawing on the newly created European Union Sectoral Emissions Data (Bayer, 2019), we show that the EU ETS reduced emissions by about -11.5% (95% confidence interval: [-16.8%; -4.8%]) in sectors that it covers compared to the counterfactual in which no EU ETS had been implemented. This translates into 1.2 billion tons of CO_2 emissions saved from 2008–2016,or reductions of 3.8% relative to total emissions.

Aside from the substantive importance of our findings given constant criticism over the ineffectiveness of carbon markets due to persistently low prices, this paper introduces a powerful statistical method for policy evaluation that travels beyond our application to the EU ETS. In fact, we believe that the generalized synthetic control method is currently underused to assess policy effectiveness and guide political decision-making, so by popularizing this approach, our work also contributes to the learning of the modelling community as a whole..

Counterfactual modelling and synthetic control

As indicated above, the main challenge for assessing whether a policy works or not is to isolate the effect of the policy, e.g., the introduction of the EU ETS in our case, from effects of other factors that change at the same time, e.g., changes to economic growth. A rigorous understanding of policy effectiveness therefore requires to compare the observable outcome of a policy against a counterfactual outcome that would have prevailed had the policy never been introduced. For us, this means we need to compare actual carbon emissions to those emission levels we had seen in a world without the EU ETS. The obvious problem here is that the latter can never be observed.

One way around this problem is to estimate the counterfactual using statistical techniques. The synthetic control method is in principle a simple re-weighting approach (Abadie, Diamond, and Hainmueller, 2010, 2015). To assess the effect of a policy in country A on outcome O, we can use a re-weighted combination of outcome O in countries B-Z (so called 'donor pool') to approximate as best as possible outcome O **before** the introduction of the policy in country A — this makes for the synthetic control. The difference between the value of O **after** the introduction of the policy in country A and the post-policy value of the re-weighted O from the other countries is an estimate of the policy's average treatment effect on the treated (ATT), i.e. an estimate of its effectiveness. While this approach was originally formulated for a policy in a single country, Xu (2017) generalized it to a multi-country setup where multiple countries introduce a policy, or 'get treated' in causal inference parlance.

Main results

We apply this generalized synthetic control method to EU carbon markets (Bayer and Aklin, 2019). A very practical challenge here is that in order to assess the effect of the EU ETS on countries' CO_2 emissions, we need emissions data for regulated sectors before the introduction of the EU ETS in 2005. For this, we construct the novel EUSED data set (available at http://patrickbayer.com/data/) that maps carbon emissions at the sectoral level from 'National Emissions Reported to the UNFCCC' and EUTL data, after accounting for differences in reporting standards.

Drawing on this data, we estimate that the EU ETS reduced CO_2 emissions in covered sectors by between -8.1% (2005–2016) and -11.5% (2008–2016) against the counterfactual. To be clear: these results do not mean that carbon emissions across Europe reduced by 8.1-–11.5% over the last decade. Reductions were much higher, of course. Instead, these reductions are estimates of additional CO_2 emission reductions because of the EU ETS within the sectors it covered on top of the decline in emissions we have seen anyways. In other words, the EU ETS carbon market policy is associated with substantial decarbonization of about 1.2 billion tons during 2008–2016.

Except for emissions from the paper industry, we find similar reduction patterns across other sectors, such as energy, chemicals, minerals, and metals. In a placebo test for emissions from the transport sector, which is not regulated under the EU ETS, we find no decrease in emissions, which increases our confidence in the estimation strategy and the results.

Contributions to learning for modelling community

Aside from the substantive importance of our findings for climate change policy and carbon market regulation in particular, our paper demonstrates the use of a very powerful statistical method for policy assessment. Synthetic control methods remain underused despite a very straightforward application. Importantly, it allows not only to estimate point estimates of policy effectiveness but also measures of uncertainty from bootstrapping. A battery of robustness tests also exists, and powerful visualizations allow for an intuitive interpretation of the results. We are confident that popularizing this type of statistical method will be useful for the modelling community as a whole, and our analysis of the EU ETS is but one application.

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Combining graphical and command line user interfaces for economic analysis: the capriR package for processing, visualizing and analysing large sets of simulation results

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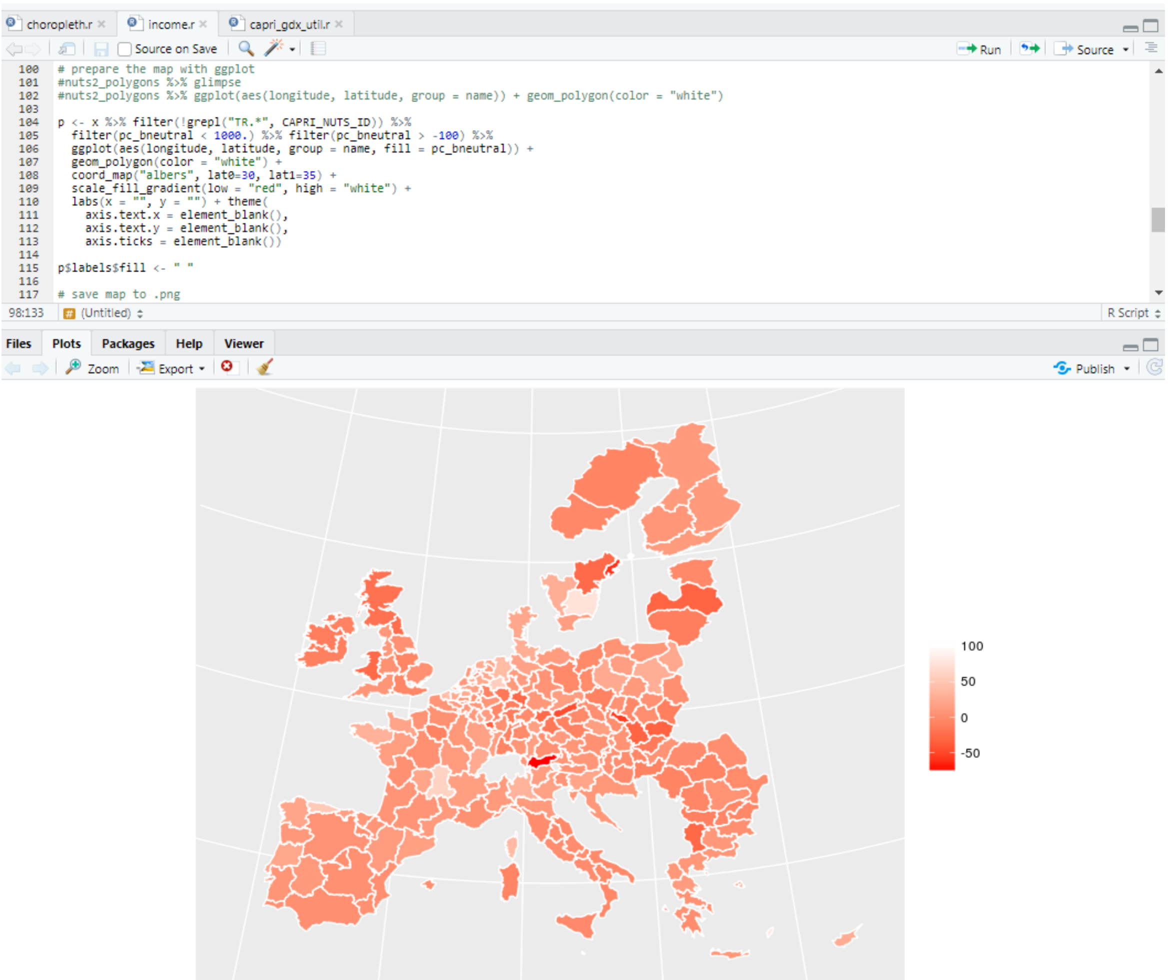
Large scale economic models naturally produce large datasets of simulated results. Analysing large amount of data is often beyond the capacity of the human mind, at least without the help of specific software tools designed for filtering, transforming and visually presenting the datasets. Many economic models also offer visual aid and easy data access possibilities for their users via graphical user interfaces (GUI). Most GUIs still require the user to do numerous and time consuming interactions with the software, slowing down the analysis of simulation results, and sometimes even hindering model users to find the relevant drivers and other causality chains in model results. The R programming language provides complementary data exploitation possibilities with its command line interface (CUI) and with a large number of optional packages for analysing and visualizing large datasets. As simulation exercises and the related reporting and data analysis need to be repeated several times during the lifetime of a typical research project, a clear advantage of user-created R scripts emerges: scripts can be executed repeatedly with a minimum effort for interaction with the software interface, each time simulation results have been updated. Data visualizations, statistical and econometric analyses based on of third-party R packages can be easily replicated and repeated in this manner.

We present an R package developed for the Common Agricultural Policy Regionalized Impacts (CAPRI) modelling system, a large-scale economic model with a particular focus on agriculture and food markets. The capriR package includes specific functions for processing, visualizing and analysing both the model databases and simulation results. capriR has been designed to complement the specific GUI of CAPRI, which remains the preferred options for quick analysis of model results and for executing the wide range of modelling tasks from database preparation until simulation runs. The relative advantages of capriR compared to the GUI include the (i) dissemination of model-databases and simulation results; (ii) automated reporting requiring additional (post-model) calculations and (iii) creating publication-quality maps and other data visualizations.

As CAPRI covers EU agricultural production activities with fine geographical detail (NUTS2 administrative regions), spatial data and their visualization, analysis is a particular challenge. capriR links CAPRI results to commonly used spatial data packages thus enabling the user to create high-resolution intensity maps or even interactive maps. capriR also includes functions for rapid access of the databases and simulation results of the CAPRI modelling system. The modularity of the R programming language allows for directly applying advanced econometric and statistical techniques from other (open-source) R packages on the data sets retrieved from CAPRI.

Although capriR is only directly useful for the relatively small user base of CAPRI, we also point out in this paper some general strategies for rapid package development for similar, large scale economic models. What makes the capriR approach potentially interesting for a wider economic modelling community is that model-specific R packages can be built with limited efforts, and under limited time for the same purposes, including dissemination of results, visualization and complex post-model data analysis. This is particularly important for modelling approaches where different types of quantitative models are linked. The need for exchanging large amounts of data (model inputs and outputs) between different model architectures poses a practical challenge to modelling groups. Model-specific R packages for data exchange offer a common software platform. The large user-base of the R programming language in the broader scientific community makes such packages efficient in disseminating model results for a general scientific audience, increasing at the same time the transparency of modelling exercises. Opening the black box of complex

Figure 1: Intensity map of CAPRI simulation results prepared with the capriR package



large-scale models by making databases and results easily accessible can lead to huge gains in credibility for the modelling community, and is also an essential part in evidence based policy making.

Below is a screenshot (Figure 1) presenting some of the spatial data functionalities of capriR.

Wildfire modelling for adaptation policy options in Europe

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This study presents a quantitative assessment of adaptation options and related policies in the context of wildfires in Europe under projected climate change. The Wildfire Climate Impacts and Adaptation Model (FLAM) is able to capture impacts of climate, population, and fuel availability on burned areas. FLAM uses a process-based fire parameterization algorithm that was originally developed to link a fire model with dynamic global vegetation models. The key features implemented in FLAM include fuel moisture computation based on the Fine Fuel Moisture Code (FFMC) of the Canadian Forest Fire Weather Index (FWI), and a procedure to calibrate spatial fire suppression efficiency.

Currently FLAM operates with a daily time-step at 0.25-arc degree spatial resolution. All inputs in FLAM are adjusted to fit this resolution. FLAM uses daily climate data for temperature, precipitation, wind, and relative humidity. When calculating the human ignition probability, a gridded population density is used. Fuel available for burning is defined as a combination of litter and coarse woody debris (CWD) pools, excluding stem biomass. We use integrated modeling approach, where biomass dynamics is provided by the IIASA's global forestry model G4M. The fire suppression efficiency is implemented in FLAM as the probability of extinguishing a fire on a given day.

The FLAM's modeled burned areas for selected test countries in the EU show good agreement with observed data coming from two different sources (the European Forest Fire Information System and the Global Fire Emissions Database). We employ climate projections corresponding to four RCP-scenarios. Our estimation of the potential increase in burned areas in Europe under a 'no adaptation' scenario is about 200 % by 2090 (compared with 2000–2008). The application of prescribed burnings has the potential to keep that increase below 50 %. Improvements in fire suppression might reduce this impact even further, e.g. boosting the probability of putting out a fire within a day by 10 % would result in about a 30 % decrease in annual burned areas. By identifying policy options that emphasize on adaptation options such as using agricultural fields as fire breaks, behavioral changes, and long-term options, burned areas can be potentially reduced further than projected in our analysis.

In the talk we will discuss policy recommendations, as well as demonstrate some visualization tools.

Parallel sessions 5

Computational and empirical issues in dynamic economy-wide models

Room 0.C
27 November
13:30 – 15:00

Using the Global Multi-Country model in ECFIN's forecast exercises

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Introduction

We present the application of the Global Multi-country model (GM) in the context of the European Commission (EC)'s institutional forecasts. GM is a structural macroeconomic model, jointly developed by the Joint Research Centre and DG ECFIN to perform forecasting, medium term projections and spillover analysis.
GM is a fully estimated model that is flexible to allow for different country configurations. The two-region version of GM (GM2: Euro Area and Rest of the World) is the main version applied for the EC forecast rounds. The three-region version of GM (GM3: Euro Area, US and Rest of the World) has been used to analyse different patterns of the post-crisis slump in the Euro Area and the US (Kollmann et al., 2016). The EMU-countries version (GM3-EMU)[1] is estimated for the four largest European economies (Germany, France, Italy and Spain), and has been used for the cross-country comparison of the post-crisis evolution of Euro Area economies (Albonico et al., 2019a, b).
The GM model builds on the estimated version of the QUEST III model (Ratto et al., 2009), from which it inherits most of its structure. In GM2, the global economy consists of two regions, the domestic Euro Area (EA) and the Rest of the World (RoW), which are connected by trade and financial linkages. The EA region is fully specified and features households, firms, and fiscal and monetary policy authorities' blocks, while the RoW has a simpler structure. The GM model falls into the class of large-scale DSGE models used for policy analysis (see, e.g. Bokan et al., 2018; Karadi et al., 2018; Erceg et al., 2006).

The GM model within the EC forecast rounds

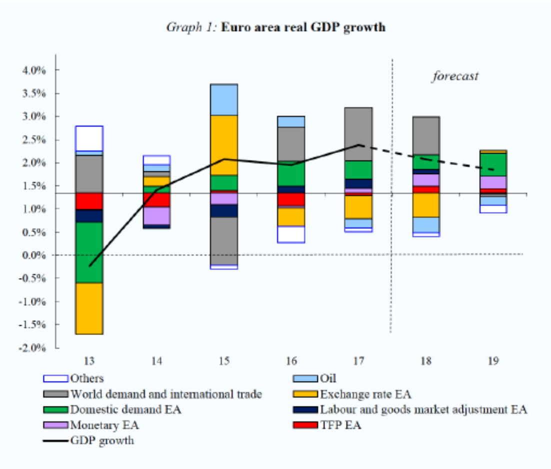
Since autumn 2015, the GM model is regularly employed in the EC's institutional forecast to understand the drivers of the evolution of euro area macro-economic variables, providing input to the Thematic Boxes included in the EC Spring and Autumn Forecast reports. More specifically, by means of a structural model, EC policy analysts can get a sound interpretation of macroeconomic data, by decomposing the dynamics of GDP, inflation, consumption, investment, trade, employment, etc. into key drivers, such as the evolution in domestic and foreign demand, commodity prices, and productivity, as well as fiscal and monetary policy.
To do so, the dataset of macro-economic variables is extended up to the forecast horizon using the European Commission forecasts. This extended dataset is analysed to recover the drivers (shocks) mainly responsible for the evolution of the macro-variables, which can then be represented in a decomposed form, where all the drivers add-up to replicate the data.

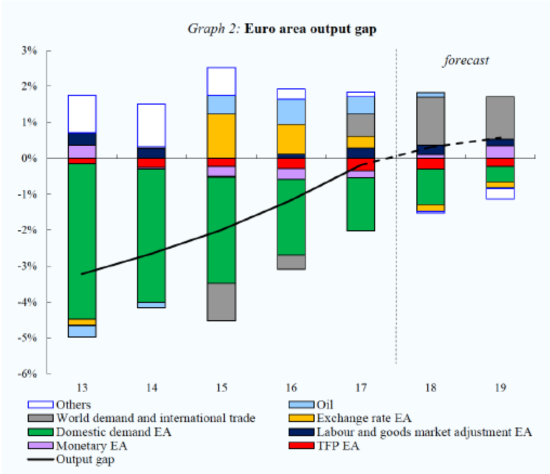
An example: the EC Autumn Forecast 2018

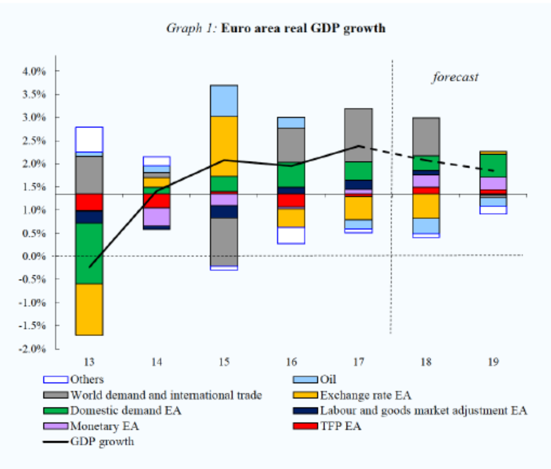
Graphs 1-4 show the decompositions of EA GDP growth, output gap, consumer price inflation and trade-balance to GDP ratio (European Commission, 2018). These graphs show how the estimation of a structural model allows the identification of the factors that drive the short- and medium-term deviations of key macro-economic variables from their long-run trends (including GDP, inflation, domestic demand, and trade balance).
In short, these model-based decompositions attribute above-trend euro area real GDP growth in 2019 to continued domestic demand growth and to an accommodative monetary policy stance (Graph 1). Domestic demand levels remain below the historical average, however, implying a still negative (although diminishing) contribution to the

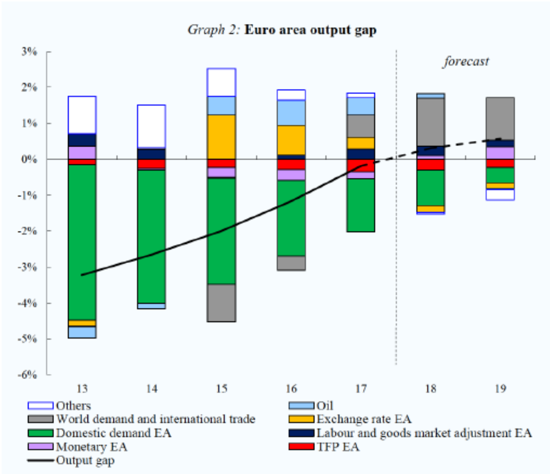
1 EMU stands for Economic and Monetary Union.

Note: The solid black line shows the historical data, and the dashed line represents the European Commission's forecast for 2018 and 2019. The coloured bars show the contribution of the groups of driving forces to deviations of GDP growth from its long-run trend of approximately 1.4%, i.e. the value at which the (solid) horizontal axis intersects the vertical axis. Bars above (below) this horizontal axis indicate positive (negative) contributions to GDP growth in a given year. The sum of positive and negative contributions matches the data (black solid line) for any point in time.









level of economic activity (Graph 2). Below-average levels of domestic demand also explain low levels of inflation in the euro area (Graph 3) and a significant part of the trade balance surplus (Graph 4) incorporated in the European Commission's forecast for 2019.

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Stationary rational bubbles in non-linear macroeconomic policy models

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Linearized dynamic stochastic general equilibrium (DSGE) models with a unique stable solution are the workhorses of modern quantitative macroeconomics and of quantitative macroeconomic policy analysis. This paper shows that stationary sunspot equilibria exist in completely standard non-linear macroeconomic models, even when the linearized versions of those models have a unique solution. Thus, those models have additional stationary solutions, if non-linearity is considered. The classic Blanchard and Kahn (1980) conditions are, hence, irrelevant for non-linear models. In the sunspot equilibria considered here, the economy may temporarily diverge from the no-sunspots trajectory, before abruptly reverting towards that trajectory. In contrast to rational bubbles in linear models (Blanchard (1979)), the bubbles considered here are stationary--their expected path does not explode to infinity. Numerical simulations suggest that non-linear DSGE models driven by stationary bubbles can generate persistent fluctuations of real activity and capture key business cycle stylized facts. Applications to both closed and open economies are analyzed.

This paper seems highly relevant for the Brussels conference, because it challenges linearized macroeconomic models that are routinely developed and used for quantitative policy analysis by the European Commission and other policy institutions. See, e.g., Giovannini et al. (2019); Kollmann et al. (2016, 2015, 2014, 2012, 2013). The results here show that the predictions of standard dynamic macroeconomic policy models can change radically when non-linearity is taken into consideration. In particular, standard policy prescriptions need not be valid anymore, in a nonlinear environment. This project contributes, thus, to the construction of more reliable macroeconomic policy models.

Further reading:

http://www.robertkollmann.com/KOLLMANN_Bubbles_NonLin_DSGE_updated.pdf

http://www.robertkollmann.com/KOLLMANN_SLIDES_Bubbles_NonLin_DSGE_updated.pdf

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The macroeconomic and sectoral impact of EU competition policy

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Dierx A., Ilzkovitz F., European Commission, Directorate-General for Competition

This paper provides an assessment of the macroeconomic and sectoral impact of merger interventions and cartel prohibitions by the European Commission over the period 2012-2018.

The macroeconomic simulations conducted using the QUEST III macro-model consider both the direct effects of competition policy interventions and two types of deterrent effects. Intertemporal deterrence effects arise from companies' expectations that the European Commission will continue its competition policy interventions at the same pace into the foreseeable future. Sectoral deterrence effects come from the transmission of the direct effects of competition policy interventions in a given market to the remainder of the sector to which this market belongs. The within-sector diffusion of the direct effects is modelled by way of a logistic function, which has been used in the literature to model the diffusion of innovation or the use of new technologies but is used here to model deterrence. Model simulations show that the total effects (including the deterrent effects) of the European Commission's competition policy interventions on GDP are sizeable, but slightly lower than the estimated impact of the implementation of the EU Services Directive. Under the baseline scenario, GDP increases by 0.29% after five years and by 0.56% in the long term. The effects on employment rise from 0.20% after five years to 0.26% in the long term. The employment effects are smaller than the GDP effects due to the increase in labour productivity associated with the increased competitive pressures.

The current paper also exploits the available information on the sector distribution of the European Commission's merger interventions and cartel prohibitions over the recent period. The version of the QUEST III macro-model used is a single-sector model unsuited to explore the industry spill-over effects of competition policy interventions. This is the reason why the macro-model simulations have been complemented by an input-output model analysis, which allows tracking the interlinkages between industries and identifying the differential effects of competition policy interventions affecting different industries of the economy.

This input-output model is used to exploit available information on the distribution of merger interventions and cartel prohibitions across industries and to explore how the avoided price increase resulting from a competition policy intervention in a given industry is transmitted to the price levels in other industries. The total price reduction associated with competition policy interventions over the period 2012-2018 is significant (-0.2%). Price reductions occur in industries that are important for the purchasing power of consumers (motor vehicles, financial services) and the competitiveness of the European economy (telecommunications, electronics). The industry spill-over price effects of competition policy interventions may be as important as their within-industry price effects. Industry spill-overs were particularly high in 2013, when two important cartels in financial markets were prohibited. Spill-overs tend to be higher in industries having strong interlinkages with the rest of the economy, such as financial services, network industries or intermediate goods industries.

Direct and indirect impacts of European Institute of Innovation and Technology (EIT) investments on regional economic growth

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Kancs d'A., European Commission, Joint Research Centre

The present study evaluates regional economic impacts of the European Institute of Innovation and Technology (EIT) investments in the period 2020-2050 using spatially disaggregated Computable General Equilibrium (CGE) model with endogenous growth engines. The model used for the analysis allows us to take into account both direct and indirect impacts of the EIT investments via inter-regional trade linkages and endogenously determined global knowledge frontier.

Innovation and human capital have been widely recognised as key drivers of a sustainable economic growth in the long-run. The European Union is implementing a number of policy instruments to promote the innovation activity in Europe including among others the Framework Programme, European Structural and Investment Funds and European Fund for Strategic Investment.

The present study focuses on evaluating the impacts of the European Institute of Innovation and Technology (EIT) investments in the period 2020-2050 using a spatially explicit macroeconomic model for Europe with a regional and sectoral detail that captures spillovers from investment in the knowledge and human capital.

In order to undertake a comparative scenario analysis and assess impacts of selected EIT investment support policies first a baseline scenario is constructed and simulated. There is no EIT supported investment implemented in the baseline scenario; baseline indicators, such as an additional investment leverage or impact on GDP, are used as benchmark against which to compare EIT policy scenario outcomes.

Second, alternative EIT investment support (counterfactual) scenarios are constructed and simulated. The policy scenario construction requires data on private co-funding rates for each year in the EIT scenario. The rest of the co-funding is coming from the EIT funds. The Horizon Europe proposal sets out the budget for the EIT (EUR 3 billion for the period 2021–2027)[2]. Further, we assume that the spatial investment pattern of the EIT will remain the same as in the base year EIT expenditure data meaning that only a subset of EU28 regions will receive the funding and that the regional pattern of investments follows the historical pattern.

The EIT investment support affects economy, society and environment in many different ways, posing challenges to the methodological framework for capturing all the impacts, as they are diverse and complex due to various inter-sectoral, inter-regional and inter-temporal linkages and interdependencies. In the context of EIT activities in the areas of research/innovation, education and business creation/support in

2 Article 9, COM(2018) 435 final.

improving the innovative performance of the Member States and the Union, three types of effects of EIT-supported investments are of particular interest: (i) demand effects (e.g. hiring of workers, machinery), structural effects (e.g. productivity and human capital growth) and macroeconomic effects (e.g. on GDP and employment). Generally, there are many more economic impacts, as well as societal and environmental effects which, however, are beyond the scope of the present analysis.

In order to calculate the direct impacts of the EIT investments in the period 2020-2050, we have calculated the impacts of EIT investment on changes in sectoral productivity in each of EU NUTS2 regions based on the estimated TFP regressions and regional data. The relative changes in productivity of each of the sectors have been translates into the changes in sectoral value added by sector and by region and the new regional GDP has been calculated as the sum of the increased value added of the sectors. Among the regions that have the largest direct benefits from EIT investments are the Provincia Autonoma di Trento in Italy, Noord-Brabant in the Netherlands, Ile-de-France in France, Oberbayern and Berlin in Germany in the order of their direct benefits. The direct benefits for these regions range between 130 and 400 million of Euros in the period 2020–2050.

Total regional effects of EIT investments can be both positive and negative meaning that economic growth of the regions that are directly affected by EIT investments can results in economic decline in some other regions. This can be due to increased competitiveness of the regions with EIT investments and the respective relocation of economic activities to these regions. The regions with the largest negative indirect effects include Massa-Carrara and Veneto in Italy, Nord-Pas de Calais and Bretagne in France as well as Arnsberg and Weser-Ems in Germany.

The largest total effects of EIT investments are associated with the same regions that had the largest direct effects of these investments on the productivity of the economic sectors. The total EU direct effect related to EIT investments impact on sectoral productivity in the period 2020-2050 amount to 2 170 million of Euros whereas the overall effects in the same period amount to 18 520 million of Euros. The EU-wide ratio of the total to direct effects of EIT investments in the period 20202–2050 is around 6. Overall about 1/3 of EU NUTS2 regions experience positive effects of EIT investments and 2/3 of EU NUTS2 regions experience negative effects of EIT investments. These negative effects are experiences not only by the regions that do not receive EIT investments but also by the regions that receive relatively small EIT investments.

Modelling the labour market and agricultural sector in an integrated CGE framework: an application to the Brexit case

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Free cross-border movements of goods, services, investment and people are the principal pillars of the European single market. The UK is preparing to leave the EU with departure date temporarily scheduled for the end of October 2019 plus a possible transition period (House of Commons Library, 2019). Whenever this happens, the UK will need to put in place new trade and immigration policies necessary to deliver the novel relationship with the EU. Ideally, the UK would like to decide immigration policy and trade policy separately such that it can maximize the outcome from each one of them. More realistically, the UK will be required to face trade-offs between trade and immigration policies especially in sectors such as the agri-food industry. A complete understanding of the effect of these combinations is therefore impossible without understanding how trade and immigration policies interact within the UK economy.

This paper investigates the effects of the interactions between trade and labour immigration policies. We apply a computable general equilibrium (CGE) model based on the GTAP 10 database specifically designed to count for imperfect native-migrant substitution across sectors and to allow for imperfect labour mobility between agriculture and the rest of the economy. The CGE model is employed to analyse the effect of different trade and labour immigration restrictions on the UK economy within the Brexit debate.

The process of relocating labour can be slow because skills are not perfectly transferable across sectors and retraining takes time and money (Campo, Forte, and Portes, 2018). In other words, workers specialize in occupations where they have a comparative advantage. Similarly, natives and migrants have different skill sets and immigration encourages workers to specialize where they have a lower opportunity cost (Peri and Sparber, 2009). Following Ottaviano and Peri (2012), we estimated the native-migrant constant elasticity of substitution (CES) by industry for the UK to differentiate the production of value added, and thus the demand for labour, by skill type and migrant/native status.

Besides, although farm and non-farm wages have moved together, there is a substantial evidence that wage differential persists in developed economies (Kilkenny, 1993). In the UK, low unemployment rates and a high number of vacancies are persistently observed in many sectors of the agri-food industry (Office of National Statistics, 2018). Following the GTAP-AGR model developed by Keeney and Hertel (2005), we have integrated a module for segmenting the market for mobile factors in the agricultural and non-agricultural sectors according to the change in relative prices and the elasticity of transformation.

We also included two further specifications. First, livestock sectors have their own demand system for feedstuff as to reflect their imperfect substitutability. Second, we allowed the agricultural sectors to have their own production system that employs other agricultural inputs as imperfect substitutes.

Immigration scenarios were based on the forecasts of the EEA net inflow of workers in the UK until 2030, the prediction window employed in this study. The first immigration shock is the most extreme and assumes zero net EEA inflow in the UK (-2.1% reduction of labour force). The second scenario assumes that there are no modifications to the current immigration policy. This would imply a modest reduction of labour force (-0.2%) to reflect the trend started after the Brexit referendum that has already witnessed a reduction of the number of EEA migrant workers in the UK. Finally, the third scenario imposes zero net inflow of unskilled EEA workers (-1.1% labour force). This option was included to reflect some immigration options considered in the UK to limit only the number of this type of workers (UK Government, 2018; Migration Advisory Committee, 2018). Immigration shocks were integrated with three baseline trade shocks: a no deal scenario, an average free trade agreement, and a version of soft Brexit as described in UK Government (2018).

Our findings show that in the UK severe to moderate immigration shocks can generate a reduction in GDP and welfare larger than a free trade agreement and a soft Brexit scenario. Moreover, UK agriculture is particularly reliant on the EEA unskilled workers. A reduction of EEA unskilled labour would reduce output and increase prices in agriculture more than in other non-agriculture sectors. This suggests the implementation of ad-hoc immigration policies such as the seasonal agricultural workers scheme and the extension of the shortage occupation lists to agricultural labourers would be needed if the UK will give up to the freedom of movement with EU nationals. These results can be employed to improve the decision-making process in matter of immigration, trade, and agricultural policies outside the Brexit debate.

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Poster session 2

27 November

A coupled modelling system for the integrated assessment of continental freshwaters, coastal and marine waters

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While the implementation of the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD) are progressing in the Member States (MS), the European Commission is building up its own analytical capacity in order to improve the understanding of the coupled freshwater and marine environment from an EU perspective. Managing as well as modelling the marine environment in a sustainable manner are only possible as long as the full continuum of freshwater systems (like rivers), coastal waters and the open sea is considered. The environmental state of all seas is largely determined by the supply of freshwater, nutrients, contaminants, litter, etc. from land. Hence, measures developed within the implementation cycles of EU's MSFD and the Water Framework Directive have – wherever possible – to be assessed for the full continuum. A step forward to support this integrated understanding is the BLUE2 project, where a freshwater resources model (LISFLOOD) and a nutrient load model (GREEN) were coupled to the marine biogeochemical models. This allows an integrated assessment of pan-European water resources from the sources on land to the sinks in the regional seas.

A database was developed including envisaged measures to reduce pollution and water abstraction, originating from the implementation of various directives. Combining climate change projections and measures enabled us to develop joint future scenarios, assuming different progresses in the implementation of the various measures, ranging from 'Business As Usual' to 'Maximal Technical Feasible'. The outcome of the spatially explicit scenarios will be made publically available on a dedicated webserver, as well as the option for users to develop own scenarios and assess the costs.

Following the regional particularities, the outcome of the scenarios with respect to freshwater runoff and nutrient loads differ strongly between the regional seas. Having developed the needed interfaces within the project, the nutrient loads scenarios will be applied for the regional seas and analysed for impacts on the marine environment, e.g. to assess if Good Ecological Status (GES) thresholds (defined within the MSFD) might get fulfilled.

A platform to manage air quality in Europe with the use of high-resolution modelling tools Application and validation in Krakow

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ATMO-Plan is a user friendly web based decision support tool, designed to facilitate the assessment of the impact of emission reduction scenarios on air quality in Europe on an urban scale at a high spatial resolution. The tool is pre-configured with EU generic data for the EU-28, users can upload their own data to further improve the quality of the air quality information obtained.

The web-tool applies an operational modelling chain starting from regional background concentrations, meteorology, fleet data and the road network with traffic intensities. Regional background concentrations for the whole interregional hotspot area can been modelled using RIO[1]. This model is based on a residual kriging interpolation scheme starting from hourly pollutant concentrations as measured by the official monitoring stations and using land use (CORINE) and population density as spatial information. A leaving-one-out validation of hourly background concentrations shows the strength of this modelling approach. Alternatively, CAMS reanalysis data have been pre-configured for the EU-28 as background concentrations.

As road traffic emission model, VITO's FASTRACE model is applied, relying on the COPERT methodology and starting from the local road network with traffic intensities and fleet information. An EU-wide traffic database for the EU-28 has been developed based on COPERT mileage per country and downscaling using satellite-based proxy data. If available, local traffic data can be applied. The city of Krakow operated the VISUM traffic model operated and the Polish fleet information has been enriched with local traffic counts.

In the operational chain, these traffic emissions are used in the bi-gaussian model IFDM model [1]. IFDM combines on an hourly resolution these contributions from local traffic with the hourly background concentrations taking into account a method to avoid double counting. Optionally, point source emissions can be added as well. The tool has been pre-configured with ECMWF Era5 meteo data for the EU-28, which can be replaced with more detailed local meteo if available. The model output is presented as time series at points of interest and annual average concentration maps for NO_2, PM_{10} and $PM_{2.5}$. The tool can be applied for both a reference year and scenarios to assess the impact of possible traffic measures. Additionally, the functionality is available to draw the boundaries of a low-emission-zone and adjust the fleet for exclusion of banned vehicles.

As part of the LIFE IP project Małopolska in a healthy atmosphere, the tool has been configured, applied and validated for the city of Krakow in Poland. Krakow is located in the Malopolska province, which forms together with the bordering province Silesia and the cross-border regions in Czech Republic and Slovakia an area with serious air quality challenges. To validate the quality of the model chain, the city of Krakow has organized two validation campaigns in summer and winter 2017. Each campaign lasted 28 days applying NO_2 passive samplers at 115 locations throughout the city. The RIO-FASTRACE-IFDM modelling chain has been operated for 2017 and successfully validated against the results of these campaigns highlighting the capabilities of the modelling chain.

ATMO-Plan is offered as a user-friendly web-based air quality decision support tool, offering an online interface for configuring the modelling of air quality scenarios and analysing the results. Users can import and export data for further processing offline and creation of more detailed input data. The application can be used for many applications such as screening of the effect of a low-emission-zone, assessment of urban air quality in high-resolution, impact of traffic reduction scenarios, environmental impact assessments and to identify which measures sufficiently improve the air quality to improve the local environmental quality and to meet EU air quality limits.

Acknowledgements

The validation study has been accomplished as part of the LIFE Integrated Project 'Implementation of Air Quality Plan for Małopolska Region – Małopolska in a healthy atmosphere' (LIFE14IPE PL 021). The development of the web based air quality decision support tool ATMO-Plan is partly funded by AirQast, a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776361.

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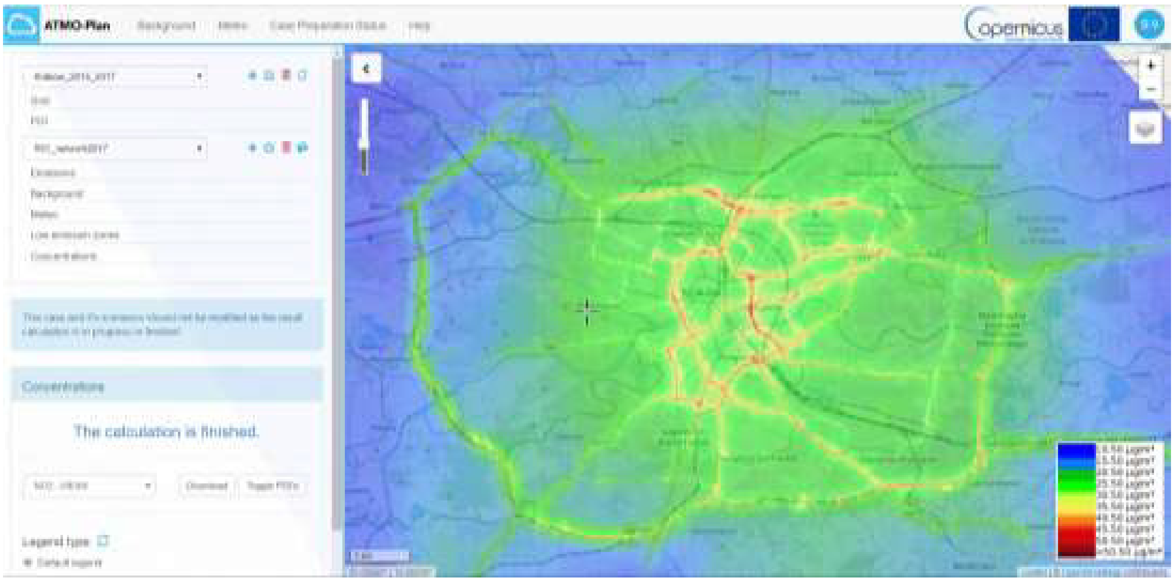
Figure 1: Screen shot of ATMO-Plan Krakow with NO_2 annual average concentrations.



Assessing the value of regional cooperation in air pollution control

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In the past decades, major efforts have been made to tackle air pollution, but despite the improvements of air quality, most of the urban population is still exposed to $PM_{2.5}$ concentrations that exceed the EU limit values and the stricter WHO guideline values. According to the European Environmental Agency (EEA), in 2015 premature deaths due to $PM_{2.5}$ concentrations were 422000 in EU, 60600 in Italy. In Northern Italy, particularly in the Po Valley, high concentrations are a common problem both in urban and rural areas. This area is characterized by high population and emission density. Furthermore, the orography and the local meteorology (low wind speed, temperature inversion) worsen the air stagnation. In the past years, interregional cooperation plans were implemented to identify concerted actions to abate air pollution.

In this work, an integrated assessment system composed of two different tools has been used (Figure 1): SHERPA (Thunis et al., 2016) and RIAT+ (Carnevale et al., 2012). SHERPA, Screening for High Emission Reduction Potential on Air tool, provides different modules to support policymakers in air quality management (source apportionment, scenario assessment, governance); furthermore, it provides the input data for optimizing air quality plans in any European region using RIAT+. RIAT+ (Regional Integrated Assessment Tool Plus), in turn, allows the definition of efficient air quality policies through a multi-objective or a cost-effectiveness approach including the measure implementation costs in the decision process. In the current study, SHERPA is used to create for a specified domain: the database of emission abatement measures (based on GAINS model database), a mapping between emission classification CORINAIR SNAP3-fuel emission classification and GAINS specific sector-fuel classification, the emission inventory on the whole Europe, and the source-receptor models needed to describe the relation between precursors emissions and various air quality indicators (AQIs), e.g., the yearly average $PM_{2.5}$ concentration.

For each geographical domain considered and for each value of the implementation costs, RIAT+ determines the best degree of adoption of the end-of-pipe abatement measures, meaning the technologies that reduce emission before being released in the atmosphere without any energy consumption modification, and the associated implementation cost.

The integrated assessment methodology briefly described here is used to analyze the impact of cooperation between Northern Italian regions in comparison with individual regional plans. Using as AQI the average yearly $PM_{2.5}$ concentration, the optimization problem was first solved on the Po Valley domain shown in Figure 2.

Figure 1. Integrated Assessment System composed by SHERPA (providing input data) and RIAT+ (implementing a multi-objective or cost-effectiveness optimization).

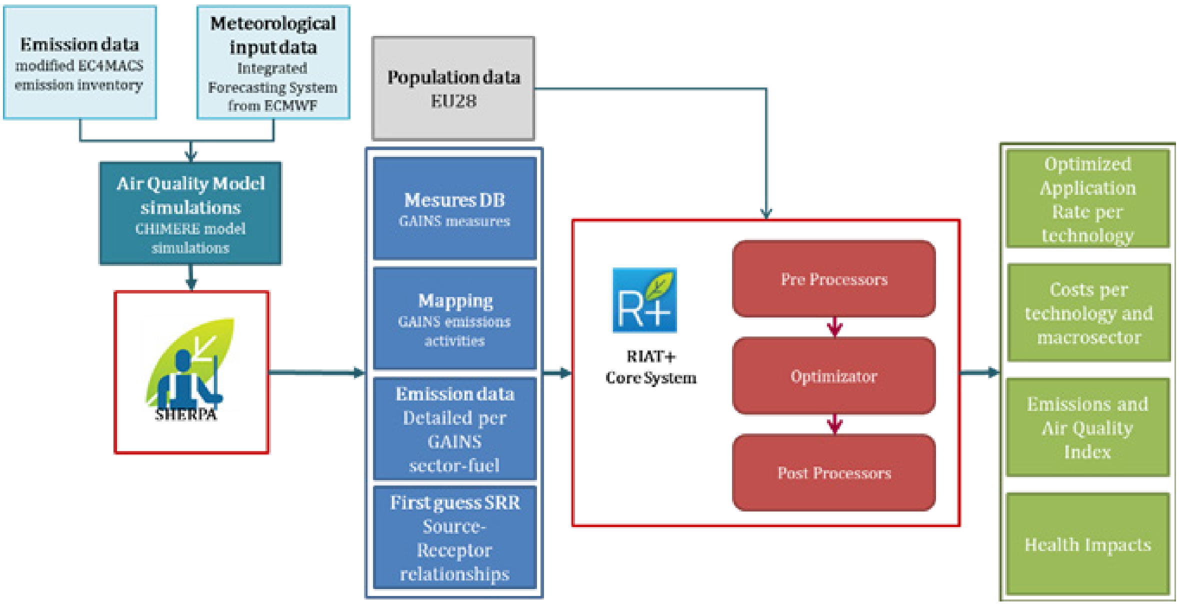
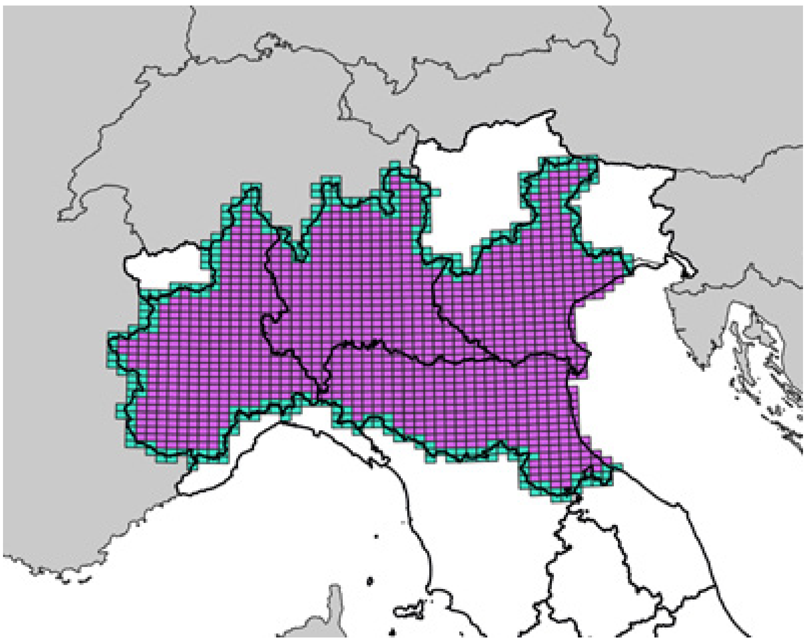


Figure 2. Case Study domain



The multi-objective optimization results are represented in the objective space, where the vertical axis refers to the AQI values and the horizontal axis to the minimum implementation cost to obtain such an AQI. Costs are computed with respect to the reference scenario CLE2020 (Current Legislation scenario), representing the application of local, regional, national and European policy already in force in 2020. Selecting for instance the optimal policies in the point of maximum curvature of the Pareto front, shown in Figure 3, the implementation cost is 67.7 M€/yr and an AQI reduction of 1.1 μg/m3 (7.8%) with respect to CLE 2020 conditions. RIAT+ can now be used over the four separate regional domains to understand what is the cost for each region to autonomously work towards the $PM_{2.5}$ concentration reduction obtained with the cooperative policy. In this case, the investment does not change appreciably for Piedmont, Emilia Romagna, and Veneto, but is higher in Lombardy where 2.2 M€/yr more are necessary, as shown in Table 1. The impacts of a coordinated policy are clear in Lombardy, especially because of its central position in the Po Valley. In Figure 4, corresponding emission reductions are presented for each precursor and each CORINAIR macrosector for the Po Valley policy (coordinated policy, CP) and for the regional policy (RP) where the emission reduction is the sum of each regional variation. Efficient measures should be implemented mainly in agriculture, road transport and domestic heating (non-industrial combustion plants) to reach the expected impact.

Figure 3. Pareto front of the multi-objective optimization computed on the Po Valley optimization domain

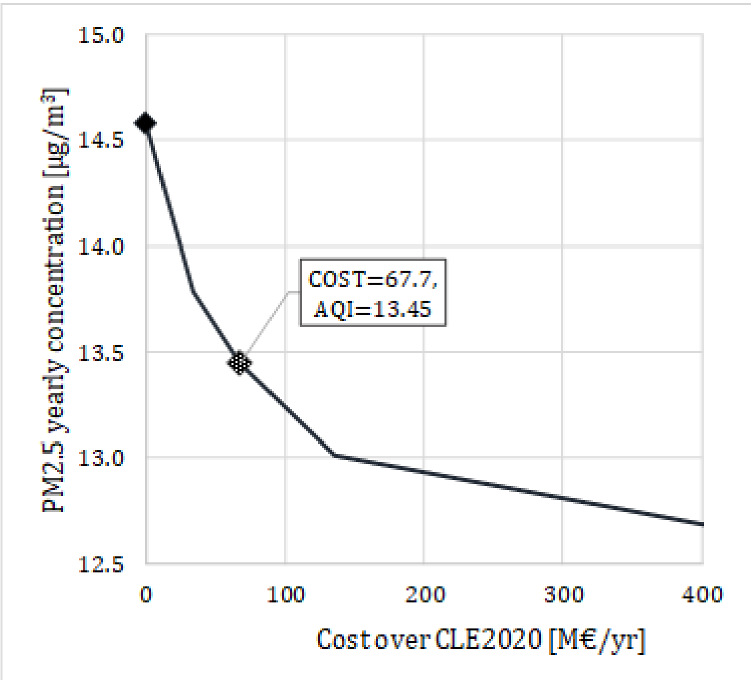
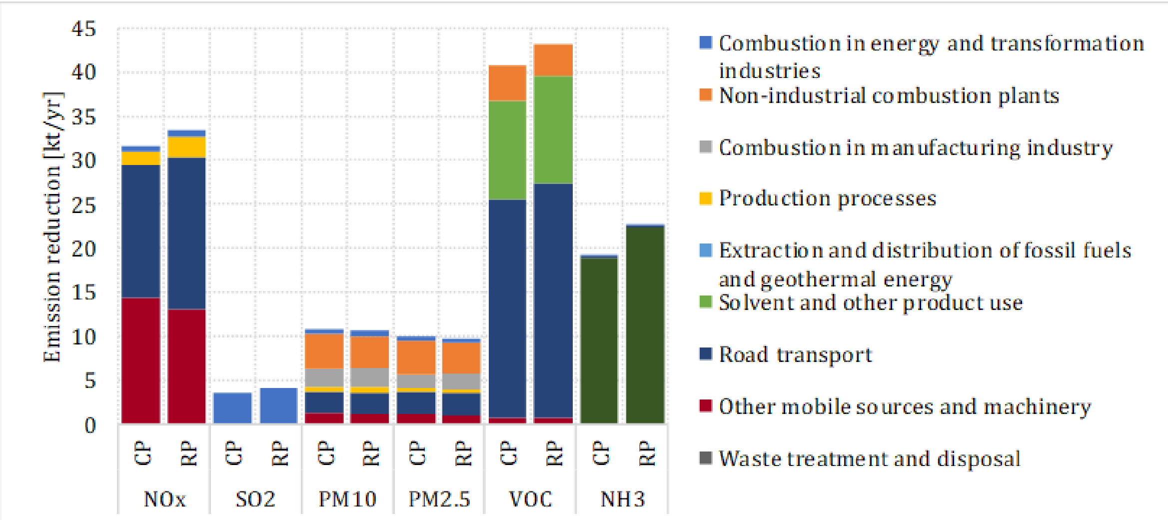


Table 1. Cost over CLE2020 in M€/yr to autonomously obtain the same impacts on Air Quality resulting from a coordinated policy between regions

Optimization domain	ΔAQI	Cost of regional policy (RP)	Cost of coordinated policy (CP)
Lombardy	8.8%	25.7	23.5
Emilia Romagna	6.9%	13.5	13.5
Piedmont	7.5%	15.2	15.2
Veneto	7.9%	15.5	15.5
Po Valley	7.8%	69.9	67.7

Figure 4. Emission reduction for each precursor and each macrosector for the coordinated policy (CP) and the regional policy (RP)



In this work, a Decision Support System that aims to help policy maker in the implementation of efficient Air Quality Plan is used in a critical European area to study how convenient is an interregional coordinated plan in comparison with actions autonomously defined by each regional authority. SHERPA-RIAT+ have proved to be helpful to understand the priority areas, where there is room for increased adoption of emission control measures, at different spatial scales. However, the range of possible improvement of air quality turns out to be quite limited because many technology-based actions should be already in place by 2020 and, in this study, we have only examined the effect of end-of-pipe measures common to all regions. Even if, for political reasons, the adoption of different measures in different regions within the same concerted action seems difficult to accept, these results emphasize the need of also examining the effect of non-technical and energy efficiency measures, which can make a further contribution to the decrease of pollutant concentration.

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Biomass in the European Electricity System: Emission Targets and Investment Preferences

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Introduction

Biomass is an important resource that can help decarbonisation in many sectors. If used in electricity generation, biomass can complement variable renewables as well as provide negative emissions if coupled with carbon capture and storage technologies. Yet, how these system services compete or complement each other is not clearly understood. Furthermore, adoption of biomass in the electricity sector is also pending policy incentives and acceptance levels. In this paper we investigate the cost-effectiveness of biomass in the European electricity system based on costs of biomass and emission requirements posed on the electricity system as policy targets and compare the results with investment preferences for biomass technologies in selected countries obtained via International Negotiation Survey (INS).

Method

To evaluate the need for biomass in European electricity system we use the ELINEPOD modelling package. The Electricity Systems Investment Model (ELIN) originally constructed by Odenberger and Unger [1], has previously been used to study the transformation of the European electricity system to meet the policy targets on CO_2 emissions. The ELIN model is a bottom up, long-term, dynamic optimization model that optimizes the investments in the power sector and has partial coverage of heat sector via combined heat and power plants (CHPs) and heat pumps. The composition of electricity system is used as input to the Electric POwer Dispatch (EPOD) model [2, 3]. This model minimizes the operating cost on an hourly basis for a selected period (usually 1 year), thus being able to investigate variations from wind and solar resources. The system models use a comprehensive database as input to represent the existing electricity supply infrastructure (power plants) [4] and hourly wind and solar resources. The ELINEPOD modelling package covers 27 EU member states (EU-27), i.e. all but Croatia, as well as Norway and Switzerland. For this study, the island states of Cyprus and Malta are excluded from the geographical scope, i.e. in total, this study covers 27 countries.

Since the amount and the cost of biomass that can be supplied sustainably and would be available to electricity system is highly uncertain, as demonstrated by Kluts et al. [5], we refrain from assuming the cost-supply curve of biomass for our model runs and instead allow for unlimited biomass use at varied prices to illustrated the cost-effective use of biomass for the electricity system. Based on previous research [6], we test three different price levels for biomass: 20, 50 and 100 Euro/MWhth (megawatt hours of heat). To estimate the effect of negative emissions on the cost optimal allocation of biomass we run the model with three different emission scenarios: reaching zero emissions by 2050, meaning that no emissions from any part of the electricity system are allowed; reaching net-zero emissions by 2050, meaning that emissions in part of the electricity system can be offset by negative emissions in another, and; reaching net-negative (–10%) emissions compared to 1990 levels by 2050. Combining these scenarios with biomass costs gives us thus nine different cases for the model.

The INS survey data on investment preferences in the energy supply sector were obtained through questionnaires distributed at five negotiating sessions of the UN Framework Convention on Climate Change (UNFCCC): the 42nd Subsidiary Bodies meeting in Bonn, June 2015 (n = 134); the 21st Conference of the Parties (COP) in Paris, December 2015 (n = 577); COP22 in Marrakech, November 2016 (n = 892); COP23 in Bonn, November 2017 (n = 944); and COP24 in Katowice, December 2018 (n = 996). In total, 3,543 responses has been collected of which 1,115 are from UNFCCC delegates residing in the 27 European countries focused in this article. The data used in this article builds on and extends previously used data on investment preferences [7]. The extended number of responses allows for a more finely granulated analysis, moving from global regional analysis to look at European domestic levels. The questionnaire was designed using a Likert-style response option format.

Results

The preliminary model results show a clear difference in biomass use among the cases. In net-zero and negative emission runs biomass is mainly used in biomass-fuelled steam power plants with carbon capture and storage (BECCS). Negative emissions are used (aside for meeting the emission requirement in –10% emissions case) to enable the use of fossil power plants to utilise the existing capacity and provide the flexibility to the system. BECCS plants are concentrated in few countries, providing negative emissions also for other member states. In zero emission case biomass is used in biogas fuelled power plants and in combined heat and power plants (CHPs) that are more evenly distributed across Europe. One can note also that even when biomass cost is extremely high (100 Euro/MWhth), it is still costeffective for the system to use some amount of it instead of other variation management options such as increased storage. Biomass is also competing with nuclear power; high biomass price means more competitive nuclear power plants and vice versa.

Survey results show varying preferences for bioenergy, but the general level of preference is rather low. A Kruskal-Wallis test provides no evidence that country of origin influences respondents' views of whether or not to direct investments towards BECCS in order to transform the electricity generation system towards low-carbon configuration in their country of residence. For most countries, the respondents neither agree nor disagree that such should be done, with a slight tendency to lean towards disagreeing. The same test provides evidence that country of origin influences respondents' views of whether or not to direct investments towards bioenergy without CCS ($p = .001$). A Mann-Whitney U test also reveals that governmental actors are generally more in favour of both bioenergy without CCS ($p = .021$) and BECCS ($p = .000$) compared to nongovernmental actors across all the selected countries represented in Figure 1.

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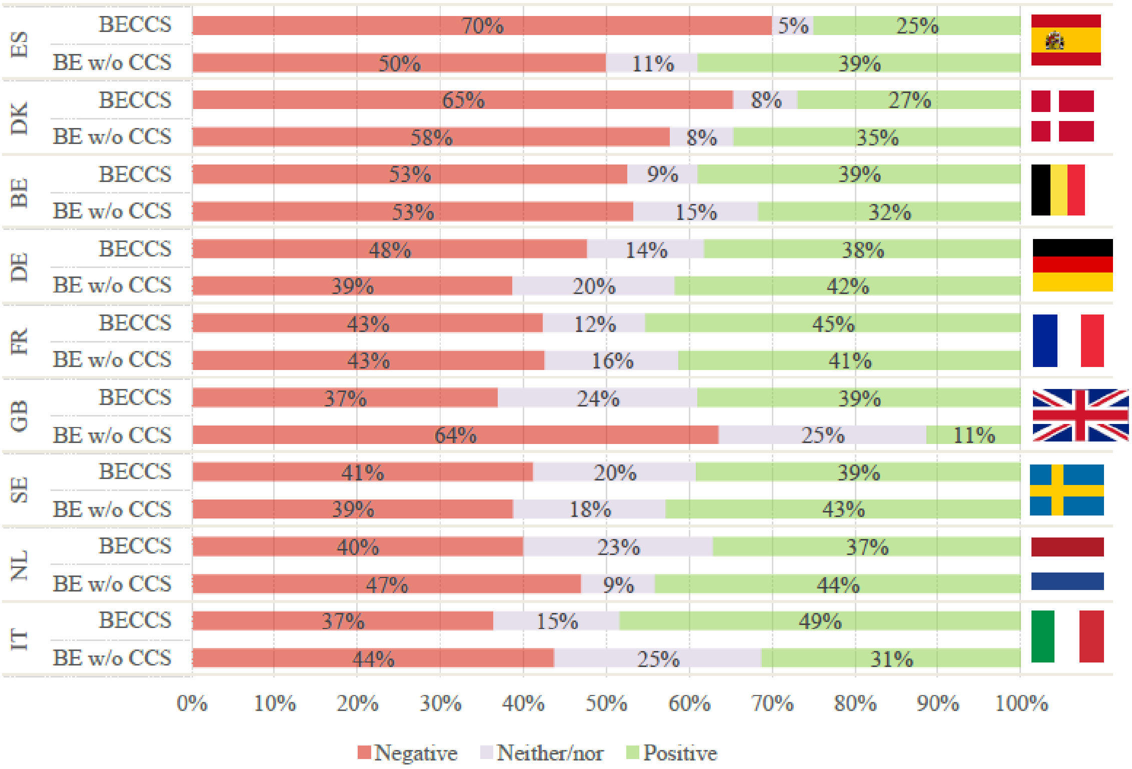
Figure 1. Attitudes of UN climate change conference delegates, from the selected countries, towards directing investments in a long-term transition to low-carbon electricity generation to bioenergy without carbon capture and storage (BE w/o CCS) and BECCS.



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Easy-to-use modelling tool for urban air pollution with very high resolution HPC simulations

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Motivation and aims

Bad air quality in many cities results in 3 million premature deaths worldwide per year according to WHO reports ([1]) and more than 70.000 deaths across the EU-28 countries ([2]). EC introduced assessment methods of exposure measurements and set up policies for ensuring citizens with clean air ([3]). Since the implementation of the Directive 2008/50/EC, modelling can be used for some assessments ([4]).

Very high spatial resolution would be necessary for accurate epidemiology exposure computations since there may be substantial differences between the concentrations of air pollutants over the city: hot spots may arise and stay at certain places regularly resulting high exposure while the overall (average) air quality indicators used in policies, are below policy thresholds. However, there were obstacles to implementation of operational models of these features for policy and decision makers, in particular huge computing power and difficult operation of applications of the required supercomputers were mentioned as main obstacles.

Using the novel research results of high performance computing (HPC), artificial intelligence (AI), cloud computing and mathematical technologies, the latter one for constructing efficient algorithms - these all let us develop and implement a suitable solution to be presented below.

HiDALGO goals

HiDALGO is a Centre of Excellence for HPC and Big Data for global systems funded by EC from Horizon 2020 ([5]). HiDALGO advances HPC and AI technologies as tools on supercomputers in order to improve data-centric computation in general. HiDALGO runs the urban air pollution pilot as well which provides a user-friendly application as service that accurately and quickly forecasts air pollution of cities with very high spatial resolution using HPC, supercomputers and tools of the CoE. This pilot will be running operationally. Further, a traffic control system will be developed and tested to minimize air pollution while keeping traffic flow constraints being satisfied at prescribed level.

Methods of HiDALGO Urban Air Pollution Pilot

To achieve these goals, the pilot has developed an HPC-framework for simulating the air flow in cities by taking into account real 3D geographical information data of the city, applying highly accurate computational fluid dynamics (CFD) simulation on a highly resolved mesh (cca. 2 meter resolution at street level) and using weather forecast or re-analysis data from ECMWF as boundary conditions. For CFD solvers both ANSYS Fluent, leading commercial software and an open source framework have been used. Dispersion of the emitted pollutants in the wind field is computed via strong coupling to the air flow computation. For uncertainty quantification an ensemble model has been developed for the urban wind flow and the pollutant information.

The emission of the traffic, which is the most significant producer of NO_2, one of the most dangerous pollutant, is computed via using either the Copernicus Atmosphere Monitoring Service (CAMS) inventory data for emissions or via the Copert-4 model applied to traffic volumes got by traffic simulations with SUMO. Traffic simulations of the demonstration city, Győr, Hungary are based upon the traffic monitoring sensor network. In the latter case the sensor network, to be implemented during the HiDALGO-project consists of a plate recognition camera system that monitors the whole traffic at the main junctions of the demonstration city, thus providing the traffic simulation with traffic information including origin-destination and trip data in real time. The traffic monitoring system will be completed with affordable cost weather and air quality sensors as well for validation purposes. Chemistry between the main components of pollution, in particular NO_2, NO, O_3 is taken into account. Emissions of the city infrastructure, in particular from heating of buildings and long range emissions are modelled by CAMS data.

Post-processing computation of features of pollutions, in particular hot spots, e.g. area in a cross section above certain concentration value, or computed local exposure values, which might be components for new policy methods are provided. Visualization of 2D (e.g. concentration maps in cross sections) and of 3D (e.g. by virtual reality tools of HiDALGO) will be also presented.

Novel mathematical technologies for modelling

To reduce the huge amount of computing resources for each analysis, novel mathematical technologies, namely model order reduction for CFD is applied in HIDALGO. This is based on, e.g. proper orthogonal decomposition and its variants which involve several offline HPC-simulations, snap-shot collection, data analysis of the snap-shots (e.g. clustering similar states into groups and dimensional reduction in groups) and then the reduced model composition for the original variables. The reduced models are less computationally demanding while losing only small part of the accuracy from the original full complexity model.

Web portal for user interface

Users are served via a web based portal where they specify the area and time period of the assessment, source of data, select from the supported HPC infrastructure and choosing the parameters of solvers for simulations. Then they launch the assessment by pushing a button. Status of the running is monitored from the dashboard. Post-processing is also run simply from the portal. The prototype of the portal was developed in MSO4SC, another H2020 project and tailored further by the subproject for industrial mathematics of the University-Industry Cooperation Centre of the Széchenyi István University.

Demonstrations

Full set of features of the assessment, in particular the traffic sensor network supported traffic simulation are ready for Győr, the demonstration city of the project. Further cities, e.g. Stuttgart are ready for the hands-on demonstration of the developed service during the presentation or the conference.

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MAQ, an integrated assessment model to support air quality policy at regional scale

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Despite the growing political and scientific concern arisen in recent years, Particulate Matter (PM), is still a major problem, especially in urban densely populated areas. In such areas, end-of-pipe measures are usually not enough to reduce atmospheric pollutant concentrations to acceptable levels. Since secondary atmospheric pollutants, such as PM10, are generated through complex and non-linear processes of production, accumulation and transport, environmental authorities need tools for building and implementing air quality plans.

MAQ model [1] is an integrated assessment model designed to support decision makers, often in the need to select air quality control policies with economic constraints. The methodology implemented can be interpreted starting from the DPSIR scheme (Drivers-Pressures-State-Impacts-Responses), adopted by the EU [2]. In particular, MAQ solves an optimization problem by iteratively changing a set of abatement measures that directly reduces emissions (PRESSURES) or alters the human activities (DRIVERS). This modifies air quality (STATE) resulting in the variation of IMPACTS. The impacts are evaluated, and RESPONSES are accordingly changed until efficient solutions are reached.

MAQ solves a multi-objective decision problem that at the same time minimizes n air quality indices (e.g. the yearly average PM_{10} or NO_2 concentrations) and the total cost to reach such indices. The decision variables of the problem are the application rate of the emission reduction measures. Two classes of measures are considered: **end-of-pipe measures**, reducing the pollutant emissions without changing the energy consumption of the anthropic activity and **energy efficiency measures**, reducing the level of fuel consumption. Such measures also include energy-switch ones (the replacement of an activity by another one that is more effective from an energy consumption point of view), as well as behavioural measures (e.g. active mobility strategies).

The methodology has been applied over Lombardy region, a densely populated and industrialized area, located in the Po basin and subject to high PM pollution levels.

The baseline scenario includes the Current Legislation requirements for 2020 (CLE2020).

Four decision problems have been solved adopting the MAQ optimization approach:

- the identification of efficient abatement measures considering, one by one, three emission sectors identified as the main contributors to the regional PM10 concentrations: (a) road traffic, (b) agriculture and (c) non-industrial combustion (mainly domestic and commercial heating systems);
- the identification of efficient abatement measures considering all the emission sectors (d).

Figure 1 shows the Pareto curve representing, in the objective space (Costs Vs. PM10 population weighted mean concentrations), the optimal solutions for decision problems (a), (b) and (c). The solution considering agriculture dominates the other ones; as this sector is relatively unregulated with respect to the other two, there are a number of effective and low-cost measures that can be adopted.

In terms of maximum potential PM10 mean concentration (Table 1), Non-Industrial combustion (c) could have the highest impact but at very high costs (1046 M€/year).

The efficient solutions, when all the sectors are considered (d), are represented in Figure 2. As expected, multi-sectorial policies have a higher impact with respect to the policies identified considering specific emission sectors. Policy A is the solution of maximum curvature. This policy allows a reduction in population weighted PM10 yearly mean concentrations of 5.6 µg/m3 at a cost of 525 M€/year.

Figure 3 shows the estimated costs and emission reductions for Policy A. Costs are

Figure 1. Pareto curves for the three single macro-sector decision problems (a), (b) and (c)

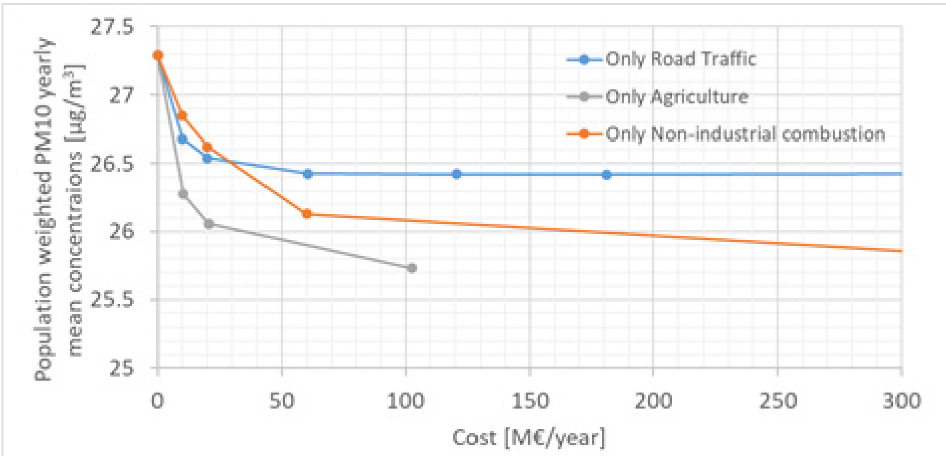
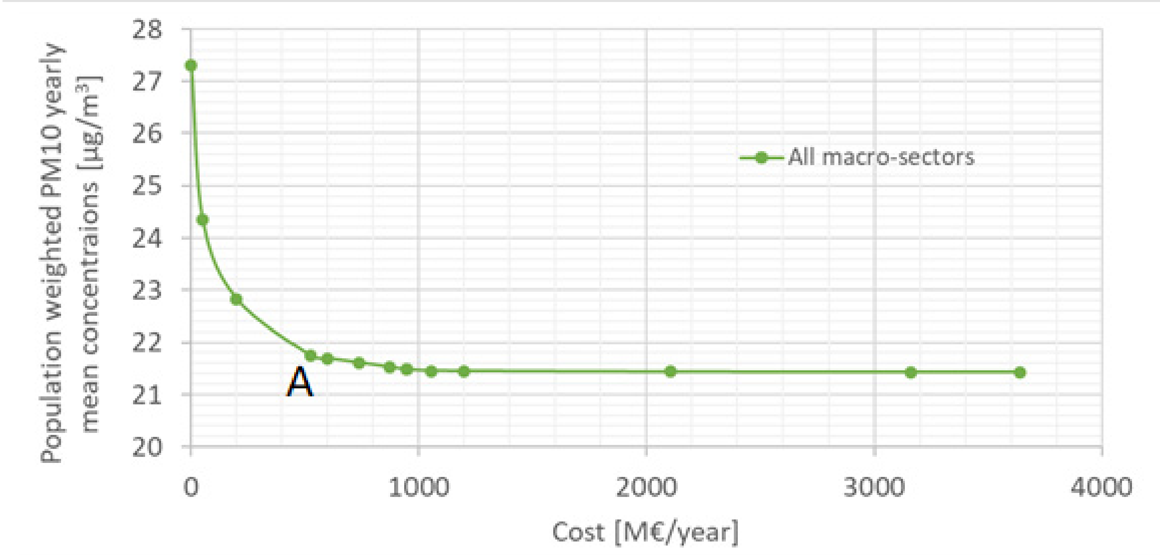


Table 1. Maximum potential PM10 mean concentration reduction and costs of measures in one by one emission sectors

emission sectors	maximum potential PM_{10} mean concentration reduction [µg/m³]	Cost [M€/year)]
Road Traffic (a)	0.9	603
Agriculture (b)	1.6	102
Non-Industrial combustion (c)	2.3	1046

Figure 2. Pareto curve for the decision problem all the macro-sectors (d)



distributed in different sectors, but highest investments are computed for 'Commercial and residential combustion plans' (2), Agriculture (10) and 'Solvent use' (6).

Premature mortality due to PM10 exposure is estimated in terms of average per-capita months of life lost [3]. Maps in Figure 4 show the health impact reduction of one by one scenario, highlighting the effectiveness of Policy A.

In conclusion, MAQ model is implemented to assess the relative effectiveness of air quality policies that consider one by one emission sectors and a plan affecting all anthropogenic activities in Lombardy region (Italy). The analysis estimates the maximum potential reduction of different sectors and, assessing costs, proves and quantifies the efficiency of a plan that includes measures for all sectors, emphasizing the substantial role of energy measures.

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Figure 3. End-of-pipe and energy measure costs (left); PM10 precursors emission reduction (right) aggregated for CORINAIR – SNAP1 macro-sectors, related to Policy A

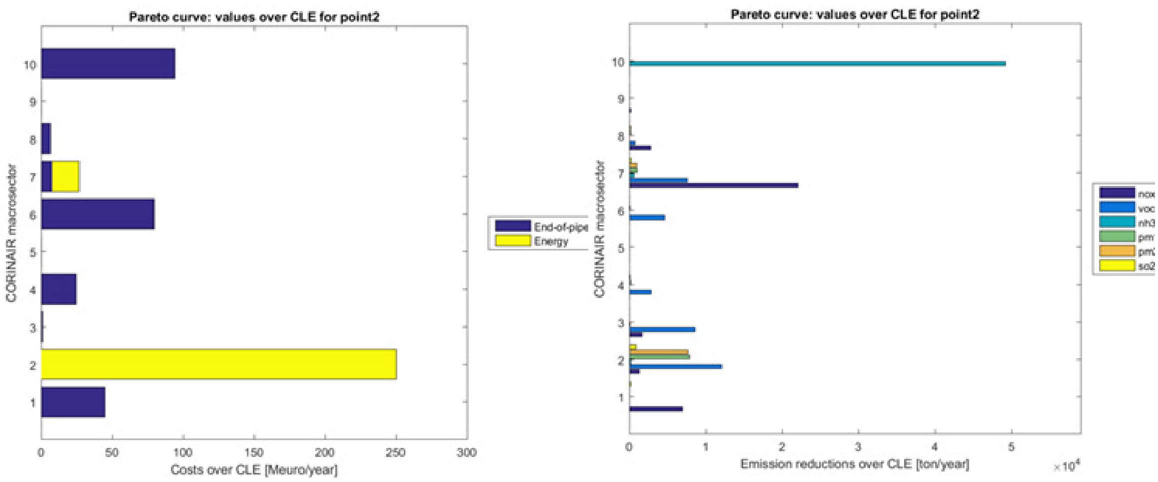
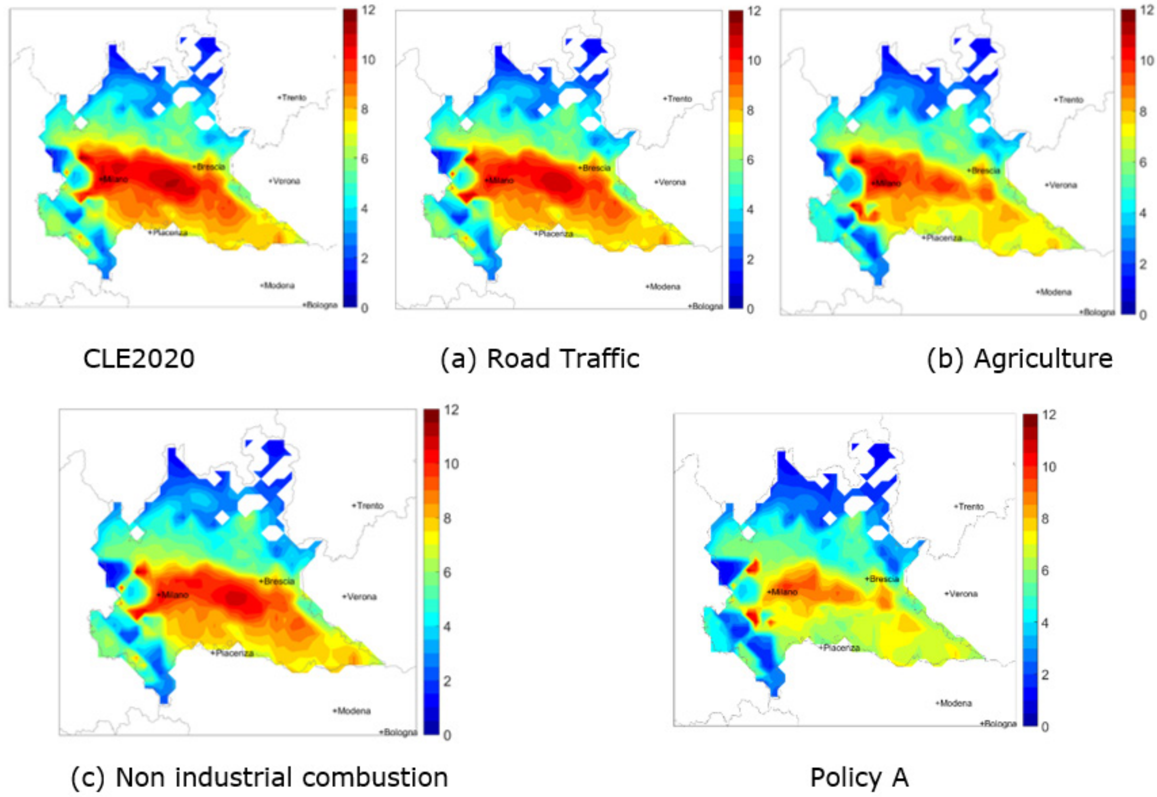


Figure 4. Maps showing per-capita months of life lost over the study domain due to long-term PM10 exposure, related to the baseline scenario CLE2020, maximum potential of measures in one by one sector and Policy A



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Modelling the renewable transition: strategies and policies for reducing energetic and raw materials costs

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The European Union must decisively engage in the renewable transition in order to minimize its contribution to global climate change. However, the structural changes required to replace fossil fuels by renewable energy are not free of costs and impacts.

Indeed, building new infrastructure for the generation, transmission and storage of renewable energy, and the adaptation process of all economic sectors and households to use renewable energy, will entail an enormous monetary investment, and a significant increase in energy and raw materials demand. Not adequately managed, those resources risk becoming bottlenecks to complete the transition.

The aim of this work is to evaluate the potential energy and raw materials costs of the transition, and to derive policy recommendations in order to minimise them. To do so, we used the MEDEAS model at EU scale.

The MEDEAS models are open-source System Dynamics energy-economy-environment Integrated Assessment models (IAM) that are currently being developed within the framework of the MEDEAS project ('Modelling the Renewable Energy Transition in Europe'). They are available at two geographical scales, EU and World, and are structured in 7 submodules: Economy, Energy, Infrastructures, Materials, Land Use, Social and Environmental Impacts Indicators and Climate Change. Being a child of the World model (nested approach), the EU model inherits the same characteristics as its parent, with the only exception that the EU version includes imports from the rest of the world.

The models bring innovative features such as the integration of Input-Output matrices in a System Dynamics model, the inclusion of supply-demand closures, the dynamic estimation of the Energy Return on Investment (EROI) of renewable energy (RE) technologies, the impact of climate change in the energy consumption and the estimation of potential scarcity of certain raw materials. Most importantly, the MEDEAS model uses a hybrid bottom-up/top-down approach, that allows for testing hypothesis from which policy recommendations can be derived.

First, a scenario named TRANS (for transition) was designed. Scenarios in the MEDEAS context are a set of hypothesis regarding the future evolution of the system that are fed to the model at the beginning of every simulation. A minimum of 90% substitution of fossil fuels by renewable energies by 2050 was the main prerequisite for the design of the TRANS scenario, and the selected hypotheses to achieve it were: stabilisation of the economy; large implementation rates of RES technologies; large increase in storage capacity; enforcing electrification of all economic sectors combined with efficiency improvements; phase-out of oil for electricity and heat generation by 2060; and an afforestation program to capture Carbon from the atmosphere.

Based on that scenario, 3 simulation experiments were performed in order to evaluate the overall effects of a) cutting the aviation sector size by half, b) increasing the recycling rates of materials, and c) delaying the phase-out of oil for electricity and heat generation.

The energy and materials costs associated with such transition scenario, and to each of the three individual hypothesis, were evaluated by looking at relevant outputs of the model. In terms of energy, results from the simulations with the TRANS scenario indicate that the initial cost of the transition will inevitably have to be covered with fossil fuels (mostly imported), with a subsequent increase in greenhouse gas emissions across Europe. Despite an initial period of energy scarcity, if the investment in renewable energy sources is maintained over time, the progressively larger installed capacity will be able to cover even larger proportions of the energy demand, reaching above 90% of the share of the energy supply by 2050.

Good planning and an adequate geographical distribution of the different technologies will be key to optimize the potential of each RE technology, and to avoid the net energy cliff that might occur if the EROI of the system becomes too small.

In terms of materials costs, only Indium and Tellurium might become a threat to the completion of the transition at European level, and substitutes of some of these materials will need to be found as soon as 2035.

Regarding the three hypotheses evaluated we conclude that:

- Reducing the size of the aviation sector by half results in savings of 4% of the total final energy consumption of the EU.
- To compensate for the scarcity of Indium and Tellurium, recycling rates of such elements would have to increase between 40 to 45% annually.
- Delaying the phase-out of oil for electricity and heat generation does not prevent an episode of energy scarcity that arises around 2030, causing a minor economic decline.

Based on these results, a set of policy recommendations aimed at reducing energy and materials costs are proposed. These policies target the stabilisation of the economy, guaranteeing supplies of non-renewable fuels to make the transition, implementing RE technologies with the highest EROIs, the electrification of all economic sectors, downsizing the aviation sector, the electrification and downsizing of the household transport sector, improving recycling rates and the construction of the high-voltage European interconnection.

Finally, the assumptions made in this work allow to meet the EU target of reducing GHG emissions by 80% with respect to those of 1990. Therefore, we conclude that the adoption of the TRANS scenario will allow the transition to be almost complete by 2050 without severely affecting people's life standards nor depleting material resources, and leaving a clear path to reaching zero emissions before the end of the century.

On the sense of applying 'Frankenstein monster' models

Kremers H., ModlEcon

My first encounter with quantitative models for policy impact analysis was a three year contract in a project called 'ECOBICE' financed by the 'Volkswagen Stiftung'. The project intended to bring together various models dealing with the impact of climate change into one big integrated assessment 'economy-climatebiosphere' model. The ECOBICE integrated assessment model combines an economic model, a vegetation model, and a climate model, with a land use model, a water model, a tourism model, and a population model with their interlinkages into one 'monster' model.

My first impression (as an economist) was that such a 'monster' would not make any sense. I nevertheless accepted the huge challenge this project offered. What better way to quickly and efficiently obtain the necessary knowledge on all aspects of climate change impact? I started with the responsibility for the economic sub model and, at the end of the project, integrating all the modeling contributions into the overall 'ECOBICE' model, see Kemfert et al. (2006).

During the project, I often compared the 'ECOBICE' model to the monster of Frankenstein. According to the novel by Mary Shelley (1869), this monster was constructed by Dr Frankenstein from body parts of a variety of dead human-beings. It turned out to be an ugly monster since, due to this large variety, these parts did not fit together well. If Dr Frankenstein would have been an economist, his monster would have looked much different (even uglier?) than if he were a climate scientist. Every model often uses similar concepts, like 'equilibrium', but it soon turned out that we all had a different understanding. Every sub model originated from a different scientific culture which caused Frankenstein's monster model to become rather 'culture shocking', hence heavily rejecting the other body parts. Every one of us was an expert on a sub model and understood their own models into the last detail. There was nobody who understood the complete model. So, how could you use such a model for policy impact advise?

Computable General Equilibrium modeling can be seen as 'theory with numbers'. In the eyes of many 'practitioners' as policy makers and engineers often consider themselves, this often makes it suspect. Nevertheless, applying Computable General Equilibrium modeling to policy advise offers large benefits, if applied conscientiously. First of all, it functions as a common language between us theorists or modellers, and the policy makers who are used to communicate in numbers. Secondly, using a consistent theory to communicate your findings provides an elaborate set of assumptions under which these findings are valid. Thirdly, in order to compute the cost of inefficiencies in the economy, one needs a benchmark which can be proven to be efficient. The Computable General Equilibrium model can be proven to fulfil the two Welfare Theorems on efficiency introduced by Cournot, Walras and others. Hence, this model offers a perfect benchmark.

The 'ECOBICE' experience provided me with a good overview of what could go wrong with quantitative modeling and its application to policy impact analysis. The paper to this presentation presents this overview, and provides my ideas on how we could possibly solve these problems. I also address some misconceptions among the various scientific cultures involved. The paper can be seen as a qualitative introduction to a follow-up quantitative study on a meta-analysis of the influence of such modeling characteristics on policy impact. Hawellek and Kremers (2003) for example already performed such an analysis with respect to modeling experiments of the US Stanford University based Energy Modeling Forum (EMF) regarding the impact of implementing the Kyoto Protocol, see Weyant and Hill (1999).

There is a theoretical and an applied (quantitative policy analysis) side to integrated assessment modeling. The applied side has many characteristics of engineering, and the theoretical side is completely left out. What is left looks like a sort of 'engineering tool'. But, the real challenge is to find the correct equilibrium between theory and engineering practices in order to come to a conscientious policy impact analysis. We will be looking for this equilibrium. Within this context, I in particularly refer to Rodrik (2016), who tries to defend the social sciences and in particular the economic sciences against the criticism following the financial crisis of 2009.

During the presentation, I hope to bring this overview and my suggestions to the audience of policy makers and modellers, open for discussion and alternative proposals, and possibly for cooperation. My presentation intends to provoke the conference attendants to think further what they are applying and why. The ECOBICE experience was a good one to learn about all aspects of climate change, but was it worth the massive costs? Couldn't we have done the same with existing small models? Is this really the best way to communicate results to the policy makers? Can we improve upon current modeling practices? At the end of the conference, I hope to bury the monster of Frankenstein!

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Policy failure in the field of electro-mobility

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The global stock of electric cars exceeded 5 million units in 2018, led by China with 2.3 million electric cars (EVI, 2019). In the same year, there were over 1.2 million electric cars in use in the European Union (EU) (EAFO, 2019). In the passenger car market, electro-mobility is speeding up. The key component of electric cars continues to be the battery. Despite declining lithium-ion battery costs in recent years (BNEF, 2018), the purchase price of an electric car remains higher than the price of a conventional car. For this reason, financial incentives are available in most EU Member States (ACEA, 2019). Policies at the EU level such as the CO_2 emission targets for new cars sold (EU, 2014b) and the deployment of alternative fuel infrastructure (EU, 2014a) are expected to promote electric car market growth, thereby contributing towards the Paris Agreement (EU, 2017). Notwithstanding this, the future market uptake of this powertrain technology remains uncertain.

To understand the factors influencing car powertrain choice, including electric cars, the JRC conducted a stated preference survey in mid-2017. Over 1,200 car owners in France, Germany, Italy, Poland, Spain and the United Kingdom answered the questionnaire (for details, see Gómez Vilchez et al. (2017)). As a result, a discrete choice model was estimated, where driving range and recharging time were identified, in addition to the purchase price, as statistically significant factors influencing choice (Rohr et al., 2019).

The need to consider explicitly the interactions of multiple factors in a complex system such as this calls for the adoption of a modelling strategy that facilitates the representation of the 'endogenous point of view' (see Richardson (2011)). This is best captured by a simulation model that uses feedback structures (Forrester, 1961) (Richardson, 1999). Two classic examples of feedback processes present in the field of electro-mobility are the 'chicken-and-egg' problems related to high battery prices and insufficient infrastructure availability. The system's behaviour over time that arises from such feedback structures is relevant for model-based policy analysis. Of interest to the policy analyst is the identification of leverage points (see Forrester (1971)).

The objective of this paper is to illustrate a potential policy failure in the field of electro-mobility by means of a modelling example, with a focus on the electric car battery price. For this purpose, a model linkage between the JRC in-house Powertrain Technology Transition Market Agent Model (PTTMAM)[1] and the Transport, Energy, Economics, Environment (TE3)[2] model was implemented. Both simulation models are grounded on system dynamics.

PTTMAM models the decisions of four main agent groups involved in the EU electro-mobility system as well as their interactions: users, vehicle manufacturers, infrastructure providers and authorities. The model is documented by Harrison et al. (2016a) and has been applied by Pasaoglu et al. (2016), Harrison and Thiel (2017a), Harrison and Thiel (2017b) and Harrison et al. (2018).

The TE3 model examines energy demand and greenhouse gas emissions from nine car powertrains, including electric cars, in four major non-EU car markets: China, India, Japan and the United States (US). The model is documented by Gómez Vilchez (2019) and has so far been applied by e.g. Haasz et al. (2018). For the purpose of this work, a sub-model that represents the Chinese bus market was added.

Figure 1 shows the default (i.e. 'no linkage') evolution of the battery price, as simulated in each model. The following assumptions underlie this figure: the battery capacity assumed for PTTMAM is 30 kWh, the exchange rate is 1.2 dollars per euro and a 10% mark-up is assumed to translate cost into price. As can be seen, the simulated battery prices differ significantly between 2013 and 2022. Whereas the PTTMAM simulation has a relatively good fit with the historical data over the period 2012-2014, the empirical evidence suggests a better match with the TE3 simulation in 2015 and 2016.

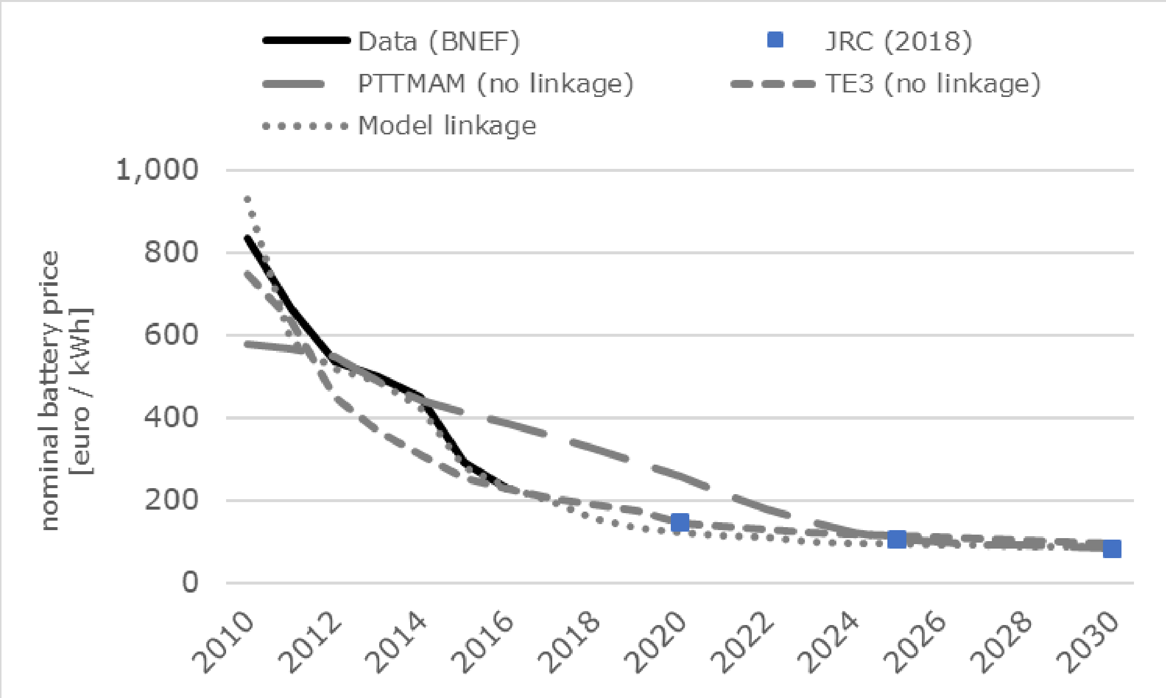
In addition, Figure 1 shows the results after linking the modules (i.e. 'modal linkage' curve). In this case, the simulated battery price exhibits a more plausible behaviour. Finally, future battery prices are shown in the figure. The 2020, 2025 and 2030 trajectory is taken from the 'middle scenario' reported by JRC (2018). The simulation after model linkage seems to be in line with that trajectory.

Policy failure may be defined in this paper as the ineffectiveness of policy measures for meeting on time a certain target that has been set to overcome a given problem. As an example, the case of Germany can be

1 Available under the EUPL at: https://ec.europa.eu/jrc/en/ptt-mam
2 Available at: http://www.te3modelling.eu/

Figure 1. Evolution of the electric car battery price

Sources: data from BNEF (2017), scenario by JRC (2018) and own simulations



mentioned: it set the target of deploying one million electric vehicles (EV) by 2020 and has offered purchase incentives since 2016 (BMU, 2019). Despite this, the one million EV target is unlikely to be met on time (see e.g. Thiel et al. (2019)).

Model-based policy analysis based on the isolated output of any of the two models would have been misleading. Once major markets influencing cumulative battery manufacturing experience (e.g. bus market, China and the US) are explicitly taken into account, a more realistic behaviour of a crucial model variable could be determined. Thus, this may provide a sounder basis for choosing a level of purchase subsidy for a new electric car.

We conclude that models that do not explicitly model feedback loops are likely to miss important mechanisms that are part of the electro-mobility system. As a result, the side effects or unanticipated consequences of well-intentioned policies may take policy-makers by surprise (see Sterman (2000) for a discussion). Therefore, our general policy recommendation is to use nonlinear models that deal with the interplay of positive and negative feedback processes. In the particular field of electro-mobility modelling, we suggest the complementary use of simulation tools that model the actions of key non-EU car markets such as China or the synergetic effects of policy measures, so that policy failure in the field of electro-mobility can be avoided.

This paper was limited to a single example and other potential sources of policy failure remained unexplored. Relevant to the context of the European Battery Alliance (EBA, 2019), supply-side constraints may jeopardise electric car market uptake (Gómez Vilchez, 2018). Further research on the representation of this and additional feedback processes in the existing models is needed. Finally, these models can be coupled with the JRC in-house DIONE fleet impact model (Krause et al., 2017) to more accurately estimate vehicle energy demand and emissions, thus building on the previous work by Harrison et al. (2016b).

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The CO_2MPAS vehicle simulation model and its role in the European light-duty vehicle CO_2 certification process

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Light-duty vehicles (passenger cars and light commercial vehicles) produce a significant share of the European Union's (EU) total carbon dioxide emissions (CO_2), the main Greenhouse Gas (GHG). The EU has so far used a series of policy instruments to curb CO_2, such as voluntary agreements and fleet-wide CO_2 targets. Current fleet-wide, sales weighted, CO_2 targets (95 g/km for cars in 2021 and 147 g/km for light commercial vehicles in 2020) are based on the New European Driving Cycle (NEDC) originally established in the early seventies. The JRC and other stakeholders have signalled already since the last decade the need for a new up-to-date test protocol. As of July 2017, the emissions type-approval of light-duty vehicles in Europe is based on the Worldwide Harmonized Light-duty vehicles Test Procedure (WLTP). WLTP was introduced to replace the old and outdated NEDC. However the introduction of the new test protocol would not be possible if the entire regulatory framework governing vehicle emissions would have to change, and most prominently the pre-existing NEDC-based CO_2 targets. In order to allow sufficient lead time to vehicle manufacturers and national authorities to adapt to the new procedure, and also to save them from the burden of double testing the vehicles over the two protocols (NEDC & WLTP) in parallel, a simulation-based approach was chosen to calculate the CO_2 emissions and fuel consumption of vehicles over the NEDC in the period 2017–2021, based on the WLTP test results. A dedicated vehicle simulation model (CO_2MPAS) was developed for the purpose by the JRC's Sustainable Transport Unit, following the request of DG Climate Action, and is currently used for the type-approval of new vehicles in Europe.

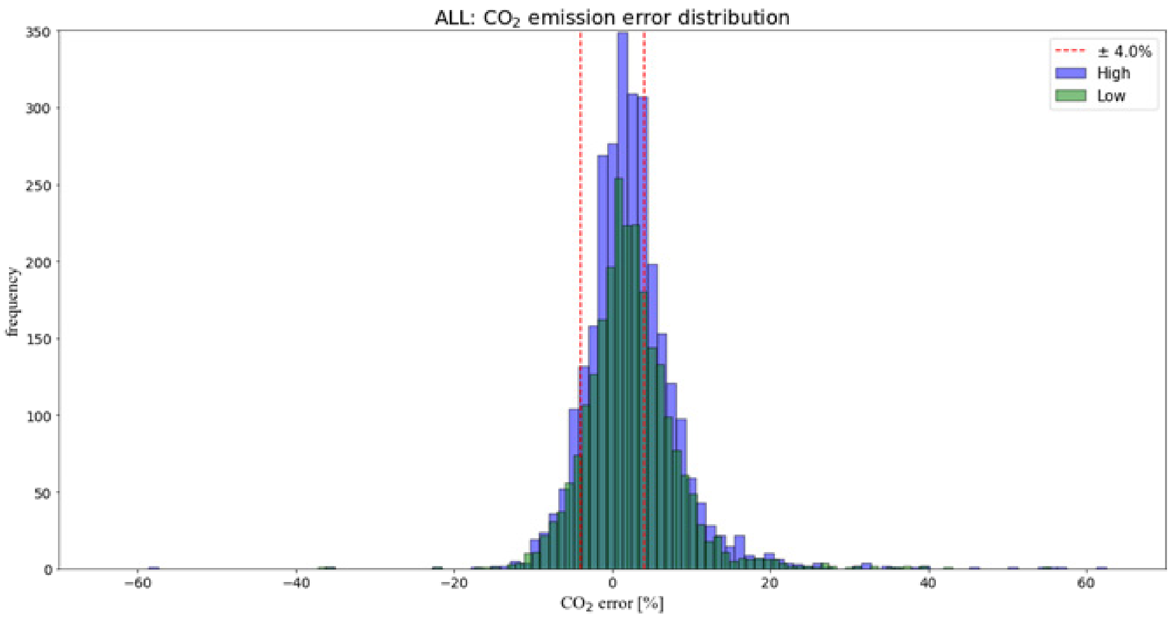
The development specifications of CO_2MPAS were challenging, as it had to be highly accurate, exhibit fast operation, and function with a limited number of input data. The core of CO_2MPAS is a backward-looking, longitudinal dynamics physical model simulating energy flow and losses at various components. Investigations indicated that the four most important factors affecting CO_2 emissions for WLTP and NEDC are, energy demand at the driveline, gear-shifting strategy for automatic transmission vehicles, hot and cold start engine fuel consumption, and the operation of specific fuel-saving technologies. In order to maximize accuracy and in lack of detailed input data CO_2MPAS has an integrated self-calibration functionality.

CO_2MPAS achieves low errors in the prediction of the NEDC cycle that in the controlled sample used for its development were of the order of 1% with a standard deviation of 3%. In the period from 09/2017 to 03/2019 CO_2MPAS has been used for official type-approval of 2882 vehicle families (2882 vehicle 'high' and 2442 vehicle 'low' configurations as defined by the regulation). The average CO_2MPAS error is 2.7% for vehicle high and 2.6% for vehicle low including possible biases introduced by the manufacturers effort to optimize their emissions towards lower values (increasing the error). More importantly, the percentage of vehicles with an error lower than 4%, the acceptance limit set in the regulation, is 69% for the vehicle configuration high and 68% for the low configuration (Figure 1). In other words, for about 2/3 of the newly certified vehicles the manufacturer's declared value was validated with CO_2MPAS, avoiding additional experimental testing. This is an important achievement as it reduces the costs and time necessary to certify light-duty vehicle CO_2 emissions during the transitional period.

Further to the above, together with the CO_2MPAS tool the JRC introduced the DICE3 server, a new channel that is used for communicating type approval information to the JRC, in order to monitor both the performance of the CO_2MPAS tool and the implementation of the respective regulation. The data produced by CO_2MPAS and received by the DICE3 have been used to support DG Climate Action for various monitoring activities and for ensuring the integrity of the implementation of the new regulation.

Regarding future activity and developments, given the expected shift towards hybrid and electric powertrains in the years to come, the development team is working on the necessary adaptations for covering also electric powertrains and conventional vehicle operation over broader operating conditions. The authors are investigating the possibility of calibrating CO_2MPAS using real-world measurement data in order to extend the tool's applicability to fuel consumption prediction over real-world operation for consumer information and research purposes.

Figure 1. Distribution of in-use CO_2MPAS error



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