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Climate-economic and macro-economic models and their policy relevance

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Nordic conference
- climate-economic and macro-economic models and their policy relevance

25th of May 2016 in Stockholm

Content

This report is a summary of the Nordic conference on climate-economic and macro-economic models and their policy relevance, which was held in Stockholm on 25th of May 2016. The conference was financially supported by the Nordic Council of Ministers and the inviting body was its working group on Environment and Economy (MEG). The Swedish Environmental Protection Agency (EPA) supported the conference in terms of project management and this report is written by Miriam Münnich Vass at the Swedish EPA. The report aims to reflect what was actually said during the conference. However, any misinterpretations are solemnly the responsibility of the author of this report.

Summary of the conference

The conference started with a series of presentations by experts and researchers from different Nordic countries. These presentations focused on macro-economic and climate-economic models used and under development in the respective countries. Several groups of models were brought up including Computable General Equilibrium (CGE), energy-system models, Integrated Assessment Models (IAMs), econometric models.

Many of the experts highlighted the challenges with modeling the different aspects of climate change on the economy. One example was the difficulty of incorporating technological change in an appropriate manner, yet it is a crucial component in the modeling. In addition, potential tipping points and disruptive events pose other challenges to modellers who often use continuous and linear functions to describe the damages of global warming or the gains of technological change. Uncertainty related to climate change, in terms of bio-physical changes as well as costs, was also highlighted as a key challenge to model.

Furthermore, many experts highlighted the trade-off between a model's simplicity and its capacity to describe the climate-economic relations in detail and that this trade-off is central to the discussion about policy relevance. The conclusions that can be drawn from the model discussions are that there is a need for different models to analyse different questions. It became apparent that it is not possible to rely on one super-model to analyse all sorts of issues. Hence, as an answer to the key question of the conference - is it possible and to incorporate climate change aspects in macro-economic models - the answer seemed to be that it is difficult, maybe even impossible, since the climate aspects are much more long term than questions often analysed by macroeconomic models. Furthermore, the effects of a changing climate are global, while the costs of taking action are national. Hence, it would be more appropriate to incorporate the effects of climate change in global models, but those are often too aggregated.

It was also pointed out that models are not aimed at giving exact figures of future costs, they should rather be used to show what mechanisms are working where and when. This means that the models can provide important insights into linkages among issues that can be useful when developing policy. Model outcomes should be interpreted as scenarios of the future rather than exact predictions. In the conclusions, it was stated that models are *"simplifying the reality, which is a feature rather than a bug"*. Models can also be used to structure the debate and bring a problem down to its fundamentals. Correctly set-up and used, they are trust building in international diplomacy and a tool to compare policy options in a rigourus manner. During the discussions it became clear that there is a continuous need to use and develop models in order to give good policy advice.

There were two presentations from OECD, one of which focused on the OECD CIRCLE project[1], and the other on mainstreaming climate change considerations in economic and sectoral policymaking. The results of the CIRCLE project give estimates of the cost of not taking action on climate change. The results suggest that the cost of inaction may outweigh the cost of action by several orders of magnitude.

On the policy side, the experts seemed to agree that the most efficient policy tool available is introducing a global carbon tax on fossil fuels. The panel also discussed the problems related to the EU Emissions Trading System (ETS) and brought up the issue of over allocation of emission allowances and the connection to the continuously low price of allowances. The difficulties in introducing additional policy measures when there is a cap-and-trade system in place were also brought up. The problem is that additional policies will have no impact on emissions since those will just be reallocating to a country within the system with less ambitious policies in place. Policy-makers pointed towards the political reality, where many different interests have to be taken into account and where there are obstacles to implementing the ideal policy.

The full program of the conference can be found in Appendix 1, a list of speaker in Appendix 2, a list of participants in Appendix 3.

[1] Cost of Inaction and Resource Scarcity: Consequences for Long-Term Economic Growth (http://www.oecd.org/env/indicators-modelling-outlooks/circle.htm)

Background

The Nordic conference on different kinds of economic models and their use in policy making was held in Stockholm on the 25th of May 2016. The overall aim of the conference was to provide a forum for Nordic decision makers, experts and researchers in the field of climate-economics and macro-economics, to engage in a dialogue on how to incorporate climate change aspects in macroeconomic policy when macroeconomic models are limited in this respect. The idea was to bridge the gap between politicians and scientists, as well as between climate policy and macro-economic policy experts in order to better understand each other's key challenges. The aim was also to encourage co-operation between the Nordic countries in the subjects' matters.

Following the Paris agreement on climate change where it was decided internationally that the temperature increase should be limited to 1.5 degrees, it is more important than ever to base macro-economic policy on robust analytical outcomes that integrate the climate change aspects. In order to reach the temperature goal, it requires a number of powerful measures to reduce emissions and adapt to a warmer climate. This will naturally have cost implications and will need to be accounted for in the development of macro-economic policy. However, macroeconomic models, which contribute with important background material for policy decisions in both the short- and long run, have difficulties in accounting for impacts of climate change. This is in particular due to technical circumstances e.g. macroeconomic models are generally used for short-term policies whereas climate impacts are long-term. The effects on the economy are global, while the costs of policy measures are domestic. On the other hand, there are climate-economic models that can analyse climate and economic questions within one single model. These models are generally much aggregated, which implies that they are less useful for short-term, national policy purposes. Hence, this often implies that the climate issue is not an integrated part when economic decisions are taken.

The OECD has during a number of years been working on what is called "policy coherence", which simply means that all policy areas should strive for the same goal in terms of welfare, environmental protection and in particular climate mitigation and adaptation. Two experts from the OECD were especially invited to talk about this work from different angels during the conference. These experts also have very good knowledge and experiences of making economic background material policy relevant, in particular within the climate change area.

A Nordic perspective on environmental economic modelling in general was recently briefly discussed in the report Making the environment count (TemaNord 2016:507), which was the result of the ad-hoc group *Complementary Measures for welfare* initiated by the Nordic environmental ministers back in 2013. One of the recommendations from the groups work was to increase awareness of the availability of existing models to a larger group of users. This recommendation was another reason for organising this conference.

Some key questions that were to be discussed during the hearing of the conference had been prepared in advance. They included:

- What can we learn from climate-economic models in order to improve the analytical results feeding-in to the macro-economic discussions and decisions?
- Is there an interest and possibility to integrate the climate issue within macro-economic models?
- If not, are there alternative strategies and cooperation possibilities, between different government institutions, in order to integrate the climate aspects in macro-economic policy?

Speakers at the conference

Moderator **Martin Ådahl**, Chief economist at the Swedish Centre Party.

Shardul Agrawala, Head of the Environment and Economy Integration Division at the OECD Environment Directorate.

Rob Dellink, Co-ordinator Modelling and Outlooks at the Environment and Economy Integration Division of the OECD Environment Directorate.

Ola Alterå, CEO of Sustainable Innovation and leading a governmental inquiry regarding policy measures to stimulare a circular economy.

Brita Bye, Researcher in Economics, University of Oslo, and senior research fellow at the research department at Statistics Norway.

Thomas Eisensee, Senior Advisor at the Swedish Ministry of Finance.

John Hassler, Professor in Economics at the Institute for International Economic Studies at Stockholm University.

Tiina Koljonen, Research Team Leader of Energy Systems research at VTT Technical Research Centre of Finland.

Nick Macaluso, Director of the Model Development and Quantitative Research Division, Economic Analysis Directorate within the Strategic Policy Branch of Environment and Climate Change Canada.

Måns Nilsson, Research Director and Deputy Director at Stockholm Environment Institute (SEI) and part time Professor of the Practice of Environmental Strategies and Policy Analysis at the KTH Royal Institute of Technology.

Conny Olovsson, Senior Economist at the Monetary Policy Department Research Division of the Riksbank.

Bert Saveyn, Researcher at the European Commission's Joint Research Centre (JRC).

Kristoffer Steen Andersen, Advisor at the Danish Energy Agency.

Thomas Sterner, Professor of environmental economics at the University of Gothenburg.

Anders Wijkman, Chair of the All Party Committee of the Environmental Objectives.

Satu Hassi, Chair of the Committee on Environment of the Finnish Parliament for the Green Party.

Janine Alm Ericson, Member of the Committee on Finance of the Swedish Parliament for the Green Party.

Monica Green, Member of the Committee on Finance of the Swedish Parliament for the Social Democratic Party.

Jonas Jacobsson Gjörtler, Member of the Committee on Environment and Agriculture of the Swedish Parliament for the Conservative Party.

Lars Tysklind, Member of the Committee on Environment and Agriculture for the Liberal Party.

Presentations

Björn Risinger, Director General of the Swedish Environmental Protection Agency opened the conference. Fredrik Granath, Chairman of the working group on environment and economy (MEG) at the Nordic Council of Ministers explained in an introductory speech the background of the conference and gave some historic perspectives of MEG.

Macroeconomic models and policymaking

Thomas Eisensee's presentation covered macroeconomic models in general and in particular MIMER, the model used at the Ministry of Finance in Sweden that looks at the sustainability of public finances in the long run. In a short exposition of history of the development of modern macroeconomic models he focused on the Lucas critique in the 1980s and its vital importance to the modern set-up of these models. Their particular features include specifying:

1) consumer preferences and firms behavior;
2) budget constraints for households and the government as well as resource constraints of the economy;
3) forward looking behaviour in the economy and
4) the full economy and not just partial sectors.

Modern macroeconomics can model how forward-looking consumers and firms respond to a policy change, by changing their behaviour both today and in the future. MIMER looks at the sustainability of public finances in the long run in five sectors. The issue of Sweden's' aging population and the fact that people will live longer as non-workers than as workers is an example of a question that can be analysed using MIMER. This demographic development has implications on fiscal policy, and can in MIMER be modeled using MIMER by linking demography, public spending and transfers, as well as labor supply. MIMER allows these matters to be analysed jointly. One issue that is of high importance at the Ministry of Finance is what will happen to savings once people live longer.

Eisensee pointed out that climate issues are generally not included in mainstream macroeconomic models and are instead often analysed separately. He exemplified with the EMEC model, at the National Bureau of Economic Research that is much richer in sectors and environmental policy measures. The EMEC model had been used to provide input to the Ministry of Finance. The lack of climate change in the general macro-economic models implies, according to Eisensee, a risk, since full understanding of how economic activities affect the climate and how feedbacks from climate change affect the economy will then not be possible. In Eisensee's view, the effect of economic activity on the climate could be included in the national models. However, it may not only be a matter of just adding an extra variable to MIMER; instead we should think carefully about which areas that are relevant for a joint analysis and which are not, in order to keep some degree of simplicity in the models. Eisensee also thought that feedback effects would require a global rather than a national model.

Brita Bye gave an account of the different economic models used in Norway. For short to medium term projections, two main macro-econometric models are used by the Norwegian Ministry of Finance: KVARTS and MODAG, where MODAG models emissions of CO_2 and is used for the annual budget analysis. For the long term, Computable General Equilibrium Models (CGE) are used and the latest versions are called MSG6 and SNoW. These models include all six greenhouse gases, NOx and SO_2. In Norway, the emergence of energy-environment-economy models occurred in the 1980s when national accounts, resource and emission statistics were combined. These models have provided policymakers with a consistent framework for analyzing questions related to the integrated areas of economy, energy and emissions. These models have in particular been used for the assessment of climate policy proposals.

Brita Bye listed a number of policy measures that can be analyzed with the Norwegian CGE model such as carbon taxes (both uniform and differentiated), tradable quotas (allocated free of charge or auctioned and also allowances within the EU ETS) as well as non-tradable quotas and other regulations. For technological developments, it is possible to make changes in the exogenous parameters in the emission model and changes in factor productivity in the economic model.

Challenges in modelling were also highlighted; in particular related to modeling technological change, where the current models are often based on existing technologies. The problem is to include innovation (R&D) in new climate technologies and to model the diffusion of climate technologies in sectors and society as a whole. There are also barriers to diffusion of new climate technologies due to externalities and behavioural aspects. These are related to learning and absorptive capacity effects as well as short-sightedness in human behavior. The latter can be better understood by studying behavioural economics.

Another challenge is related to different kinds of uncertainty e.g. technology, policy and climate uncertainties. Furthermore, empirical knowledge of technology and barrier parameters are also a challenge, where one mostly rely on ex-post empirical analyses of energy and environmental policies.

As an example of hybrid modelling performed in Norway, the KLIMAKUR2020 project was mentioned, in which they analysed what the social abatement costs of meeting global, European and domestic emission caps within 2020 would be (20% reduction in emissions compared to forecasted levels in 2020). The design of this analysis was to insert data on industry-specific technological options in the MSG-TECH model for emission-intensive manufacturing, petroleum and road transport. The MSG-TECH model then determined endogenously what technology options are cost-effective for a given policy. The conclusions were that half of the abatement is due to investments in climate technologies, whereas the rest come from down-scaling and reallocation of resources to other activities. The marginal abatement costs of achieving the targets were relatively high, approximately 1500 Norwegian kr/ton CO_2 (equivalent to 160€/ton CO_2).

Success of soft-link solutions is more likely to occur if both models are operated by the same/closely collaborative teams. There is more potential in hybrid modelling, for example to analyse energy efficiency, factor use and cost development over time. Though, there is an optimum for how detailed a hybrid model should be. Since it should be suitable for macro-economic policy analyses, it should be kept simple.

Brita then presented the CGE model named SNOW, which stand for Statistics Norway's World model. SNOW is a family of models, where the initial global model includes the rest of the world endogenously and SNOW-No focus on Norway and models the rest of the world exogenously. Different aggregation levels are possible, such as industries and regions. This group of models are suitable for focusing on energy

and climate policy analyses. For example the model contains detailed modelling of energy and emission-intensive sectors. The key drivers of the model are technological development and diffusion. It contains more realistic factor market impacts and responsive output in petroleum, agriculture and the fisheries sector. The model covers different emissions (process) and air pollution (local) and is based on the GTAP structure, programmed in GAMS/MPSGE.

The SNoW-No is based on the Norwegian national accounts, energy and environmental accounts and is modelled as a small open economy with the rest of the world exogenous. A representative agent maximizes welfare. Income stem from labour, capital and natural resources. Government collects taxes and provides government goods. The production technologies are based on nested CES-functions and labour and capital are mobile between sectors. Fossil fuels (crude oil, gas and coal) production are endogenous and limited by the resource potential. International trade is possible and modelled using armington-elasticities, where imported goods and domestic goods are imperfect substitutes. Consumer preferences are also represented by nested CES-functions. Policies and measures include taxes, subsidies and transfers. The model determines production, consumption, import and export of different goods, relative prices, resource use, CO_2-emissions and other emissions.

According to Brita Bye, consistent and high quality data are necessary at all steps in the modelling process, hence it is vital to update data and parameters regularly to get each step of the process accurate, from economics, via technology and energy to emissions. Carbon policy analyses will imply future challenges, these are in particular related to technological change and diffusion; implementation of new known technologies (bio-fuels in transport, CCS in power production etc.) and determining what the relevant costs are. The analysis should cover unilateral, regional and global analyses and assess the potential important interaction effects and emission leakages. It will be important to understand barriers and behavioural economics and include uncertainty aspects in the developments of models.

Kristoffer Steen Andersen shared his experience from working with the Danish model called InterACT, which is using the TIMES energy system model and links it to a fairly simple CGE model. As a starting point for his presentation, Andersen presented a definition for an ideal policy advice model. Three criterias should be fulfilled in order for a model to serve its purpose as an evaluation tool for policies. These are: i) contain a thorough representation of potential and realized technological changes, ii) be based on a microeconomic foundation to be able to account for how firms and consumers will decide among future technology options, given utility maximization and profit maximization and iii) account for general equilibrium feedbacks to reflect how altering consumers' and firms' choices impact the economy at large.

Andersen proceeded by presenting the intERACT model. The interaction between the models consists of changes in energy demand by households and industry and changes in the prices and cost shares of energy services, electricity and district heating as well as energy subsidies and taxes.

As previous speaker Brita Bye, Andersen highlighted technological change and how to incorporate this process into the models as a major challenge. When a model is used, a specific energy system is chosen and this affects the outcome. To answer questions such as how competitive the world energy sector is and how people consume energy, the underlying technology is crucial.

Andersen continued by pointing out that the aim of his work is to engage in a dialogue with policy makers. Models should, in Andersens view, provide policymakers with several scenarios for what will happen when a new policy is introduced. In his view, making models relevant to policy makers requires that the models are not too complicated and that they do not provide single answers - this could, in

Andersen's view, lead us into a *"pitfall of perceived accuracy"*. Rather, modellers should choose an open approach where variation in input is allowed and the results are expressed in terms of a range. Andersen also mentioned the importance of inviting non-modellers to the dialoque at an early stage.

Andersen ended his presentation by two open questions concerning how to take global and regional scenarios into account in national climate-economic models such as the intERACT. One idea was to use growth and price projections from global models (i.e. the OECD model ENV-Linkages) to capture global mitigation and adaptation scenarios. Andersen also suggested that it could be possible to work on common scenarios for the Nordic countries based on the Nordic energy perspectives or using the TIMES model, which is commonly used in both Sweden and Denmark.

Climate-economic models and policy challenges

John Hassler gave a brief introduction to his recent research, where he and his colleagues have created an integrated assessment model that analyses the climate, the carbon cycle and the economy. Hassler described how he started his work within this field after experiencing that issues related to climate change were not being sufficiently addressed in the international macroeconomic research community. Hassler identified a need to build a new model, and the idea was to create a transparent model for policy use that builds on standard macroeconomic theory with the purpose to demonstrate both policymakers and other macroeconomists that macroeconomic theory could be a useful tool in addressing climate change.

Hassler pointed out that the interdisciplinary approach, where natural scientists contributed with guidance on how to simplify the scientific climate models for the purpose of integrating them in a macroeconomic setting, turned out to be crucial for the project outcome.

The main conclusions that Hassler has drawn from his research is that by using a fairly stylized macroeconomic climate model, one can compute an optimal global carbon tax. The three main elements that need to be included are the flow elasticity of damages, global GDP and the duration of emitted carbon that remains in the atmosphere. In addition, the model uses a standard macroeconomic approach where agents discount the future. Hassler stressed that the results will depend on the assumptions the modeller make about the value of parameters such as the subjective discount factor, and emphasized the importance of transparency on this point.

Hassler drew five policy conclusions of this work:

1) The level of the Swedish carbon tax is reasonable given the fact that we do care about the future and it will not destroy or harm the economy;

2) Since coal has a flat supply curve (relative to conventional oil), it is relatively price-sensitive. This implies that a tax on coal would reduce the demand and hence the supply of coal. On the other hand, conventional oil that exists in a limited amount and has an ordinary upward sloping supply curve would and should be used up completely;

3) There is evidence that the tax level required would be fairly modest and would thus not be harmful to growth;

4) The model shows that the optimal tax can be determined from a very simple model that does not take technological change and other parameters into account; hence it is easier to implement a tax rather than regulating the quantity of emissions. To illustrate this point, Hassler compared this to limiting the road use in cities, where a road tax has proven to be far more efficient than restricting the number of cars that can enter on a given day;

5) Work on technological change shows that a tax could alter the speed of technological change via changes in energy prices. He stressed the need to take into account that there is a trade-off between higher growth in energy efficiency versus growth in other types of efficiencies. Hassler clarified that the results were relevant only for a limited amount of global warming due to the uncertainty associated with warming over 3-4 degrees.

Tiina Koljonen contributed with a presentation on Energy-Environment-Economy (E3) models. Koljonen laid emphasis on the various interactions between national, regional and global economies and talked about societal issues such as poverty, access to energy services, urbanisation and health as well as environmental issues such as emissions from land use and biodiversity. Koljonen argued that the climate and the economy interact in a very complex way, and that any effort to do quantitative modelling therefore needs to follow a systematic, transparent and – in particular – multidisciplinary approach. Her view was that due to this inherent complexity of the societal system, there is room for a group of models describing different aspects rather than aiming to capture everything in one single model.

She continued with a description of VTT:s working process and stressed the importance of a multidisciplinary approach, using the competence of a heterogeneous group of individuals. She also added that the values of the models are not solely in the scenarios they produce; they also serve as a learning process for the experts who work with them.

The E3 models used at VTT enables analysis of the outcomes and evaluation of efficiency of implemented policies. The E3 models also serve as tools to explore future scenarios and risks associated with different policy options today.

Koljonen emphasized that any long term scenario produced by an economic model should not be regarded as a forecast. Rather, it helps policymakers understand the development of the economy and potential impacts of their policy choices. It is an analysis of alternative pathways.

Koljonen provided a description of the government program for climate change. According to the new targets, the share of renewable energy in energy consumption in Finland should be above 50 %. Furthermore, the use of mineral oils should be reduced by 50 %, domestic energy sources should provide over 55% of the energy, and the share of renewables in the transport sector should reach 40%. In addition to this, the government has decided that coal in energy production should be phased out. These policy changes has called for the launch of an ambitious multidisciplinary research project, including detailed sectoral land use modelling and health impacts, as well as integrated modelling using multisectoral E3 models.

Koljonen proceeded by mentioning the need to quantify and include more research areas such as the humanities and social science in the macroeconomic framework. As the main challenge for the E3 models, Koljonen identified their increasing complexity. The policy relevance of a model is highly connected to how well the experts can communicate their analysis to a broader audience. Thus, there might be a need for both more complex and simpler models and for these to work as complements to each other. She concluded by

stressing the importance of communication and collaboration between stakeholders, decision makers and researchers from different fields.

Comments on the previous presentations

Thomas Sterner started his presentation with some comments on earlier speakers. He agreed with John Hassler that taxes are the optimal way to reduce emissions. However, he was not certain that a modest tax level would be enough to sufficiently decrease the level of emissions. The current level of the Swedish carbon tax, which is comparatively high internationally, has not managed to deliver an emission level close to zero. A similar global tax level has better potential, but may not be sufficient to reach the ambitions of a carbon free economy. Sterner pointed to the fact that so far only a few countries of the world have implemented a carbon tax. If a global tax was implemented, this would of course have a larger impact. The main argument for using a carbon tax is that it can ensure both low profits for fossil fuels producers and high prices for fossil fuel users. He continued by pointing out that the falling prices on fossil fuels observed today provides an ample opportunity to impose this tax and avoid "consumer wrath" as well as the green paradox. The green paradox implies that may create incentives for producer to extract more fossil fuels. Furthermore, he said that a tax allows for additive measures for reducing emissions, whereas a cap and trade system will imply carbon leakage to other member states if additional measures are implemented. Sterner stressed that Sweden has imposed a relatively high carbon tax and this has not distorted the economy. Furthermore, he pointed out that Sweden need to improve on the current carbon tax system by avoiding new exceptions from the tax and to make the tax more general across sectors.

Sterner also shared his view on the cap and trade system, EU ETS. He said that the markets have not been able to solve the emission problem with this type of bottom-up structure. The explanation was that the emissions rights are not ordinary goods, but created by political decisions which mean that there is no natural demand for them. There is an inherent problem of the system when politicians must distribute emission rights across countries and over time. Another inconvenient aspect of emission rights is that it will be hard to allow for further reductions of emissions once the initial quantity has been set if we, for example, are able to introduce more renewable energy. Sterner concluded that emission rights however may have a potential as a policy tool at a regional level and that there is a possibility to link similar regions or countries in a decentralized system. However, on a global level there is too much heterogeneity for an inter-linked, decentralized cap and trade system to be efficient.

Another issue that Sterner raised was what he viewed as policy incoherence, where we observe multiple layers of policy because policy makers are impatient. Sterner ended his presentation by suggesting that both general and more detailed models are needed for a complete analysis of the interaction between the climate and the economy.

The economic consequences of climate change: insights from the OECD CIRCLE project

Rob Dellink contributed with a presentation of the OECD project Cost of Inaction and Resource scarcity: Consequences for Long-term Economic growth (CIRCLE). The aim of the CIRCLE project is to assess the economic consequences of climate change. The project focuses on how environmental issues affect the economy and it takes as a starting point the consequences of inaction. The idea is to provide a

basis for comparing the costs associated with implementing various policies. The Environment Directorate at the OECD has worked with a heterogenous group of experts with knowledge about how climate change will affect various market and nonmarket sectors.

The CIRCLE project uses existing impact estimates from the relevant academic literature, and collaborates with experts from various fields, computes the costs of environmental damages on the macro economy and analyses the economic adjustment to environmental damages. Damages are calculated in OECD's multi-sector, multi-region computable general equilibrium model called ENV-Linkages, up until 2060. By using a production function approach, impacts are linked to specific drivers of growth. Furthermore, the model can incorporate autonomous adaptations via sectoral adjustments and international trade. An aggregated model within the CIRCLE-project uses the baseline and the damages predicted by ENV-Linkages to produce stylised calculations up until 2100.

The CIRCLE project focuses on how specific elements of the economy are affected by climate change, rather than using an ex-post measure for the whole economy such as GDP. Areas that are analyzed within the model are agriculture (the impact on 8 crop sectors and fisheries) coastal zones (capital and land losses due to sea level rise), health (diseases and labour productivity losses from heat stress), energy demand, tourism demand and capital damages from hurricanes. A few areas are dealt with in standalone analysis, such as the fatalities from heat waves, urban damages from river floods and biodiversity losses. Dellink pointed out that a challenge ahead is to quantify the impacts from large-scale disruptive events. The CIRCLE project does not include policy suggestions, but focuses on cost of inaction.

The main messages from Dellinks presentation were that all regions will observe negative market and non-market impacts if climate change is met with inaction. Parts of Africa and Asia will suffer the largest losses. The estimates are up to 8 percent of GDP loss and the uncertainty can imply even higher figures. Losses in agriculture and health are the two factors that will have the largest impact on total damages, followed by tourism demand and coastal zone damages. Dellink emphasized that losses will spread across sectors and regions and that the estimates show that all regions will be affected, either directly or indirectly. Other important non-market consequences mentioned by Dellink were how other events such as melting of icecaps, circulation changes and biome loss can cause further damages.

Dellink also showed how the predicted damage associated with inaction is considerably larger compared to the projection given an optimal carbon mitigation policy. In addition, the uncertainty range around the central projection also decreases in a scenario where the optimal policy is implemented compared to the scenario with policy inaction. Using output from the ENV-Linkage models, Dellink also showed that the costs from residual impacts will be lower given an optimal mitigation policy, compared to the policy inaction scenario.

According to Dellink, the level of robustness in the existing literature on the economic consequences of climate change is low, and this is due to a failure to realize how sectors and economies are interlinked. Furthermore, the costs will increase more than proportionally with temperature and the consequences are unavoidable and enduring.

Dellink also raised the issue of evaluating a life, which is an issue that must be dealt with when discussing the cost-benefit schemes of limiting the negative consequences of climate change. In economics, the concept of statistical life is frequently used but Dellink questioned the applicability of this concept in an international setting.

Dellink pointed out that ambitious adaptation and mitigation can reduce future impacts and limit the downside risks. The distribution of policy costs and benefits across regions and sectors will not be proportional. In general, the models imply that both regions and sectors need to shift towards more services. Dellink stressed that some of the scenarios that are likely to take place are very damaging in terms of GDP. These harmful outcomes should be a main driver of policy. If policy-maker find a solution when the total amount of emissions is already large, some damages are already inevitable due to the slow depreciation rate of emissions.

Shardul Argawala focused on the policy relevance of climate-economic and macroeconomic models. Agrawala meant that a fairly widespread view is that models can tell policymakers very little. However, Agrawala is in favour of researchers Jan Rotmans and Bert de Vries more nuanced approach to models, by viewing them not as "truth machines" but rather as heuristic devices in exploring the future.

The role of the Integrated Assessment Models (IAM) is thus to provide policymakers with scenarios, not predictions. The IAMs can be used for analysing long-term economic costs and benefits of mitigation. However, this is not the only policy relevant analysis area that the models cover. They can also be used to study the macroeconomic consequences of specific policies, unilateral versus collective action, leakage, burden sharing, distributional and employment effects as well as adaptation planning. To approach these questions, one can use the IAMs combined with other tools and inputs that are relevant for economic modelling, in an iterative process.

Agrawala continued by presenting three different types of analysis produced by OECD's Environment Directorate. Long-term outcomes are analysed in OECD Environmental Outlook, where the consequences of policy inaction has been the major focus. Agrawala meant that this report has an agenda setting role within the field of consequences of inaction. Environmental feedbacks on long-term growth is analysed within the CIRCLE project, which had been presented more in detail by the previous speaker Rob Dellink. Macroeconomic, sectoral and distributional implications of climate policies are analysed in dedicated working papers. Two such papers that has had considerable policy impact according to Agrawala are "Towards Global Carbon Pricing: Direct and Indirect Linking of Carbon Markets" by Dellink et al. and "Addressing competitiveness and Carbon Leakage Impacts Arising from Multiple Carbon Markets" by Lanzi et al.

The models have been used to make the case for policy reforms, for example by showing income gains from unilateral removal of fossil fuel consumer subsidies in emerging and developing countries, while at the same time managing the distributional impacts that removing such subsidies have.

Agrawala also stressed how econometric research can work as a complement. As an example, this has been proved useful when analysing the impact of policy on productivity growth. Using a stringency index as a measure for the amount and quality of a country's climate mitigation policies, OECD analysts have looked at what happens to measures such as GDP and investments when stringency increases. A preliminary result is that after an increase in stringency, investments decrease. However, this decrease is not persistent and in the long run, there is no effect.

Agrawala also made the observations that in general, the most important role of modelling at the OECD is to serve as a policy making tool. This is, in Agrawala's view, especially true for the work on the environment at OECD. The existing models have had considerable impact on policy. The collaboration between economists and environmentalist puts the issue of global warming into a new context and by doing this a broader audience is becoming aware about the seriousness of the issue. Furthermore, the models serve as a vehicle for a structural dialogue with other sectors, stakeholders and policymakers. Agrawala concluded by pointing out that in order to make models more policy relevant, it is important to include the policy clients in the framing of key questions and to promote a transparent communication of the limits and uncertainties of the models. Technical peer reviews and consulting expert and relevant communities has been another key to improving the OECD models.

Martin Åhdal, moderator at the conference, asked the politicians to provide a starting point for the discussions by answering how policy-makers use economic models in their work?

Satu Hassi pointed out that models are of frequent use in her work as a politician. She expressed a concern for what she perceived as unawareness of how the economy is affected by climate change. In particular, the effects of postponing mitigation and adaptation actions, which may limit the choices available to politicians. In addition, Hassi noted that disruptive events can provide possibilities as well as challenges and mentioned unexpected technological breakthroughs and the Syrian conflict as examples that are already affecting policy-making.

Lars Tysklind was of the view that economic modelling is a relevant instrument to have as a starting point for discussions, but pointed out that policy making is not science. Rather, it's a qualified guess about the future and the models do not always capture this.

Janine Alm Ericson said that results from models are used in her work. However, she pointed out that it is important that the models improve when it comes to including the costs of inaction in order to guide policy makers in the right direction.

Jonas Jacobsson Gjörtler agreed with previous speakers and said that results from economic models are frequently used by politicians and supplied by committees of experts. This means that politicians seldom have a deeper understanding of the models from which they use the results. Gjörtler said that his view was that politicians have trust in that Swedish authorities' provide objective information. As a politician he does not get involved in what type of model the experts use. Gjörtler also pointed out that policy-making involves an intricate process of weighing different interests, which is not always possible to model.

Monica Green said that the outcome of economic models is useful for politicians, but that they seldom understand the models in detail and hence have difficulties in knowing what goes into the model in terms of data and assumptions and also the models applicability in different circumstances. She talked about the history of environmental policy and the good steps taken in Sweden.

Martin Ådahl then gave the experts in the panel a chance to comment on previous issues raised.

Måns Nilsson stressed the need of speeding up the effort to work on costs of climate inaction in terms of showing the negative effects on the economy. He said the knowledge of the costs of inaction has increased due to the work done by the OECD and the Stern Review, but that more research on the benefits of action is required. He mentioned the work done in the New Climate Economy project, which was initiated by some Nordic countries and the UK. A modeling team at the LSE in London decided not to use conventional models to assess the co-benefits of climate action, since the models cannot grasp these kind of benefits yet. The project was instead focusing on a number of case-studies, where models where used.

Conny Olovsson commended the conference as an important initiative since the values at stake and the cost associated with inaction are too large to be ignored. Concerning the use of models, Olovsson underlined that they above all can be viewed as guidance to which policies not to use. He also pointed out that bad policies may be worse than inaction - some policies will induce large costs on the economy, but contribute little to the reduction of emissions. Models are vital to give policy-makers the knowledge of what policies will work and what policies will not work well.

Nick Macaluso said that modellers must be specific about which models are used for which time spans and purposes. There are varieties of models available and it is extremely important to use the appropriate model for answering a specific policy question.

Ola Alterå thought that different tools should be used for different settings, and mentioned OECD as the convenient forum for macroeconomic climate models. The use of models is problematic in the public debate and in national policy making, according to Alterå. This is due to the problem of accurately modelling technological change, disruptive events, structural change, etc. As an example he brought up the issue of the national emission reduction target connected to the Kyoto Protocol. The national target had required a 4 % decrease in emissions and it was at the time estimated to cost 1% in terms of GDP reduction. Sweden was however able to mitigate 16 %, much higher than the set target in only 8 years. If those 16% emission reductions had been incorporated in an economic model, the cost would probably have turned out to be very high of such policy and no politician would have decided to go for such an ambitious target. Alterå meant that presenting politicians with the scenario that in 40 years, GDP will be reduced by 1.8 % does not provide much guidance for policymaking today.

Anders Wijkman said that his impression from the experts' presentations was that the ideal climate policy would be a global tax on CO_2 and if that is not feasible, politicians should refrain from action since anything else is not cost-effective. Anders wondered what policymakers should make of this statement since in the political world, ideal conditions are rare.

Anders Wijkman pointed out that emissions trading or a tax is far from enough to tackle global warming - there is also a need for supporting innovations and investment since an increase in the carbon tax that drives emissions down to zero would be prohibitive for production. Wijkman also turned to Sterner and Hassler regarding their remark that "*it's all about coal*". Since Sweden does not use coal for its energy production, would the argument made by Hassler and Sterner imply that Sweden should refrain from implementing any carbon policies on a national level?

John Hassler responded to Anders Wijkman's concern by pointing out that it is a complete misunderstanding that if the optimal policy cannot be implemented one should restrain from action. In this case, Hassler argued, we need to compare policies that are suboptimal and choose the best option available. Hassler explained that his view was simply that we are obliged to consider the effectiveness of policies. If the most efficient way for Sweden to reduce global emissions is to concentrate the efforts on reducing emissions abroad, by recommending a carbon tax in other EU member states, rather than phasing out oil at home, then this is what should be done.

Martin Åhdal then turned to the OECD experts and asked them to make some remarks on the discussions so far and share their reflections on whether new macro/sectoral models are needed.

Rob Dellink responded that within the CIRCLE project, there is a separate model for the agricultural and the energy sector. These are then combined with a macro-economic model and for analysis of the very long-term (2100) there is also a link to an integrated assessment model. Hence, a sweep of models is necessary for analyzing different questions. To respond to the first question, Dellink agreed that carbon taxes needs to be the cornerstone in the policy structure to tackle global warming, since it is such a cost-efficient tool. In addition, there need to be alternative policy measures where we know that the carbon tax has failed. This is in particular related to the short-term and behavioural aspects. For example to overcome the scepsis of CCS and to get this technology implemented. Another area where a carbon tax fail is with disruptive technologies in the long-run, there we need complementary measures.

Shardul Agrawala made the point that climate policies are implemented in a society where there are already different other policies implemented such as investment policies. Hence, there is a need to change existing policies so that they are aligned with the climate goals. We also need to look at the goals of the policy. Is the tax there to reduce emissions or to raise revenue? It is of high importance that policies provide consistent signals in terms of carbon prices and investment policies. Agrawala took the example of energy taxes, where diesel and gasoline are taxed differently in many countries. Furthermore, there are tax-exemptions for company cars in many countries today. All these issue, only related to taxes, need to be fixed as well.

Discussion on technological progress and how that can be modelled

Conny Olovsson said that technological change is a complex process, which is not yet well understood which is a reason for why it is often viewed as an exogenous element (determined outside the model and inserted as a fixed parameter) in the models. He described the historic development of modeling technological change, starting with the Solow model and then Paul Romers work on endogenous technological change. In their research, Olovsson and his colleague worked on an endogenous method where the estimated response of technological progress is determined by natural resource scarcity, in particular fossil fuel price changes.

Måns Nilsson raised the issue of cognitive bias and meant that one major cognitive limitation in the scientific community is a bias towards the current, implying an underestimation of the rate of change. Måns pointed to how the International Energy Agency consistently underestimates the rate of price change of new technologies in their reports. To illustrate this bias towards the current, Nilsson mentioned how batteries for electric cars soon will reach a price level which implies that these cars are comparable in price to conventional cars if there is enough investment. The modelling community had not picked up on this development. Måns wants economic researchers to somehow recognize that these extreme and unexpected events occur.

Nick Macaluso responded to Måns Nilssons' claim by raising the issue of cost competition of different technologies. It is not the absolute price change of new technologies that should be of interest, but rather how the prices of new technologies relate to the price of fossil fuels. In the models it is always the conventional technologies that will dominate. You need to parameterize differently to get new technologies as a solution in the model results. In the oil sector there is also considerable technological progress to be taken into account.

Ola Alterå replied that he agreed that the fall of oil prices do have some importance. However, the rapid fall of solar cell energy prices observed today will cause a robust change in the energy market as soon as it falls to the same level as oil prices.

Anders Wijkman meant that when modelling technological development of energy systems, we have to take into account the dimension of returns to investment and ensure that investments in the green energy sector have a higher payoff than investments in the traditional energy sector. In the future we need to invest in renewable energy and not in conventional fossil fuel, hence we need to study this area of return to investment in more detail and I am directing this issue to the OECD.

Questions from policymakers to experts

1. How can the models take into account that policy making consists of a balancing of conflicts of interest?

2. Since there is a trade-off between different areas and we do not want to end up with a one dimensional focus - can we construct models that take all aspects into account?
3. Can we simplify the climate-economy models to follow the same structure as the cost-benefit analyses we have in other policy areas?
4. How do we deal with disruptive changes in the climate or the eco-systems?
5. How do the models deal with technological change?
6. Is GDP the only relevant measure of damages, given its imperfections?

Conny Olovsson commented on question 3 by claiming that there is a widespread perception that models work like a black box and that they are very complex. This is why modellers need to be transparent with the restrictions and parameters they use in their models. Olovsson also pointed out that the intersection of macroeconomics and climate is a fairly new research field. However, it is fast-moving and today some of the world's most prominent economists are doing research in this area.

Ola Alterå commented on John Hasslers previous statement that it is optimal to implement a carbon tax on coal to reduce emissions. Alterå said that theory and practice differ and that policy-making is not as simple as in theory. We cannot close down industries in Sweden due to their coal use.

John Hassler highlighted that Sweden has implemented several ambitious policies. The comparatively high carbon tax in Sweden is in his view the most efficient policy the country has to reduce emissions since the tax has made it unprofitable to start coal power plants in Sweden. Furthermore, Hassler added, Sweden's economy continues to work and progress with positive growth and this provides an important example for other countries to follow. He pointed to the fact that the global price on emissions is still very low and sometimes even subsidised. Sweden as a country should in the future focus more attention on reducing emissions abroad. Subsidies on fossil fuel should be taken away and it could be a useful policy measure to buy ETS allowances. The allowances are not very costly and to buy a large amount would reduce the number of allowance in circulation and hence raise the price of the remaining quantity.

Brita Bye meant that there is no such thing as a single model that can include all aspects, answering question 2. On the contrary, more models are needed but there is also a need to make the same core assumptions within the models in order to ensure that the same framework is being used. This is the case even if they focus on different areas of the economy. CGE models can be used for budget issues for analyzing both short- and long-run polices. This is in order to compare the outcome of different policies. Bye also made the remark that the GDP measure has shortcomings, but it is the only standardized measure widely available in terms of data.

Tiina Koljonen went back to the topic on non-linearities and tipping points, question 5. She explained that so far, the models used in Finland have not been able to integrate this aspect but together with researchers within future studies, different scenarios are constructed. It is a major challenge to quantify non-existing technologies and estimate the potential lifetimes of these and their costs. To create storylines is useful. She also mentioned that behavioural and social issues are hard to model.

Shardul Agrawala meant that it is possible to use the models and study different outcomes than GDP. In response to question 3, Agrawala pointed out that in principle, the models can produce long run outcomes for the climate and the economy. However, cost benefit-analysis is more complex in the climate-economy setting, since the costs for reducing emissions are carried by individual countries whereas the benefits are global. Agrawala also agreed with other members of the panel that a major flaw in most climate-economy models is their inability to capture non-linearities like large scale disruptive events. This is also true for the

CIRCLE project where a simple damage function is used. It is doable to analyse welfare, climate change, etc and the benefits are global and the costs are national.

Rob Dellink commented that the core feature of economic models is their potential to highlight trade-off arguments. Models need to show mechanisms rather than just numbers. To the question on using GDP as a measure of welfare when modelling potential losses or gains of climate change, Dellink responded that there are many other measures available. OECD uses Better Life Index for some analysis but GDP is more common since the concept is widely known across different sectors. Dellink concluded that the priority is to get the basic message across and GDP has proven useful for this purpose.

Anders Wijkman agreed with John Hassler that it would be a good idea to buy up emission rights as a climate strategy. However, he also noted that whenever EU has tried to reduce the number of emission rights within the EU ETS, there is political resistance especially from Eastern European countries. If Sweden were to buy emission rights, there is a risk that resources are spent on a strategy that is subsequently pushed back by other EU member states.

Hassler responded to this by noting that buying emission rights would not be a very expensive policy since the carbon price is relatively low.

Satu Hassi reminded the panel that according to EU law, tax decisions can only be made unanimously by all EU countries which meant that ETS was viewed as achievable in political terms. Hassi also noted that this is an illustration of how policy makers always work in a cross path between different interests. Hassi agreed with previous speakers that ETS has not contributed to the reduction of emissions as much as policy makers had hoped at the time of implementation, and that her impression was that the bulk of reduction in emissions is attributed to innovation in the area of renewable energy. This is thanks to the different support programs for renewables. For example, feed-in tariffs work well in practice in many countries such as Germany. This has for example led to the fact that solar energy has dropped dramatically in price. This could also be a reason for being able in Paris to agree on an international agreement.

Lars Tysklind agreed with earlier speakers that the ETS is not a well-functioning carbon reduction measure. Furthermore, Tysklind pointed out that the Committee on Environment and Agriculture, of the Swedish Parliament, is working to make models more useful for policy-making. This implies that they aim to get a better understanding of what the results actually says and also what they do *not* say. Political decisions impact on model outcomes.

Monica Green mentioned the problem with having foreign, large, heavy vehicles on Swedish roads. How can we get rid of the emission problem caused by these vehicles and is there a model that can give policy advice on this issue?

Måns Nilsson expressed the view that the ETS system was highly flawed. At the time that the ETS was drafted, policymakers viewed tax as equal to cap and trade/ETS since it was just a matter of defining emission prices or emission quantities. According to Måns, the potential efficiency of the ETS was harmed by the political process, which resulted in a too generous quantity of allowances and thereby a rate of change in emissions that stays close to zero. Måns identified what he viewed as an excessive focus in the EU on monetary integration rather than fiscal integration in the early 1990's as a cause for the failure of ETS to reduce emissions. Tax should have been possible in 1990.

Martin Åhdal turned to the panel to ask how the ETS system could be improved to fulfill its purpose.

Tiina Koljonen answered that a major challenge with estimating an optimal level of emission rights is related to the discussion about technological change. In each period, modellers compute an allocation given

the existing technologies. This makes it hard to predict how the demand for emission rights will change in the future.

Nick Macaluso meant ETS can be improved either by restricting the amount of permits in the ETS system or to allow more countries to join so that demand for the permits increase. Macaluso also raised the issue of the assumption that agents in the economy act according to rational expectation. It could be the case, Macaluso argued, that agents have irrational expectations with the implication that their response to a price level is not consistent. Instead of adopting their behavior, agents get used to a new price level (higher or lower) and revert back to their previous level of demand. He also mentioned that Canada is suggesting a cap and trade system for the country and to link it with the Californian system. A tax in Canada had been estimated to be approximately 168 dollar/CO_2 while a cap and trade system would sell allowances for approximately 28 dollar/CO_2. There is currently a high surplus in California and it has been argued that it is due to the effectiveness of this policy tool.

Satu Hassi explained that in her view, the use of 1990 as a base year for the ETS system is a major flaw in its construction, since some Eastern European members had remarkably low levels due to the recent collapse of the Soviet Union and that these levels increased considerably during the subsequent years. Hassi made the observations that the experts present at the conference all advocate a carbon tax - nevertheless cap and trade is currently being implemented in many regions across the globe. She concluded that her hope was that the ETS system would improve, since this was at least to prefer to a system without restrictions, and that policy-makers currently constructing cap and trade systems are able to learn from the flaws of the EU ETS.

Ola Alterå was skeptical towards using models as the main determinant for long term decisions. However, models do provide important guidance for policymakers, especially in short to medium run scenarios. Alterå also wanted to align himself with those who argued that a higher tax on carbon would be the most efficient policy tool. He also mentioned the suggestion of incorporating a floor price in the EU ETS. Ex-post evaluations of measures needed. There is a lot of opposition in Sweden to raising the carbon tax.

Anders Wijkman shared his view on ETS: “Hot air was avoided by choosing 2005 as the starting year” still over allocation. According to Wijkman, this caused an excessive supply of permits and consequently, prices have not risen considerably. Wijkman pointed to the failure of political systems, as the cause of this development, where the European Commission not being willing to take efficiency measures regarding the EU ETS. There has been tension between renewable experts and climate experts in the European Commission. Wijkman also argued that in reality policy-makers must focus on both national and international efforts to reduce emissions, if we are to reach the long term target of reducing emissions by 80-95%. The trading sector has its own life. There is also a need to look at the trading and non-trading sectors in the EU. It would be fantastic if modeling can show how to reach target, especially since we know that it is suboptimal the way we do it now.

Jonas Jacobsson Gjörtler raised a question regarding Hassler’s earlier statement that the focus for new emission policies should focus on coal. As an example, Gjörtler brought up how new technologies might make it possible to only produce biofuel-driven cars. Jonas wondered if this, according to Hasslers reasoning, is an unnecessary development since it focuses on the reduction of oil use.

Hassler responded that what he was referring to was what can be viewed as conventional oil, which implies that the extraction costs are low and the supply is limited. It is optimal from a social point of view to use up all the existing oil, Hassler argued, since the marginal social value of doing this is higher than the marginal cost. Based on this reasoning, Hassler argued that even if we reduce oil use in Sweden, it is socially

optimal to use up all oil globally. Coal, on the other hand, exists in almost a limitless amount which implies that it is optimal to limit the amount of coal we use, due to the emissions unrestricted coal use would cause.

Hassler also responded to Gjörtler's question on whether new technologies for replacing oil do not have at least a potential to be efficient in reducing emissions. It follows from the results that it is socially optimal to use up all the oil, combined with the notion that investment in technologies and efficiencies in one sector implies less of such investments in another sector, that it is not urgent to develop substitutes for oil now. In other words, we will use all the oil either way and if we focus on developing technologies to replace oil now, these technologies will probably be outdated when the oil stock has been depleted around 2050. Regarding uncertainties, Hassler again emphasized that the models cannot say anything about the consequences of 6-8 degrees heating. On the other hand, Hassler argued, there is no real need to focus on this since the introduction of a relatively modest carbon tax could make a global heating of that level highly improbable. Hassler concluded that a well devised policy that is not especially costly is all that is required for us to stay in the decent world, if there are no tipping points. Furthermore, he said that it is relatively straightforward to compute this tax, as long as no large disruptive events occur.

Rob Dellink emphasized that economic models cannot provide an optimal policy option, answering question 2. The models simply highlight the tradeoffs and may point to problems of a certain policy but it is up to policy makers to value the different options. Regarding ETS, Dellink agreed that the modellers had not accurately predicted the optimal amount of emission rights but on the other hand, they quickly identified that there had been an over-allocation. In Dellink's opinion, the main problem was that policymakers did not follow-up on the early warnings that the ETS would not work due to over allocation.

Ola Alterå thought it was a major flaw of the ETS system that it does not allow additive policies. Additional policies will imply too little demand for emission rights, which in turn will cause prices to drop dramatically. The ETS failures are mainly due to the provision of national allocation plans in the first trading period and in later phases due to the generous distribution of allowances by the European commission.

Janine Alm Ericson made the remark that strong conclusions are drawn from models that are not sufficiently robust. This shows that the models must improve, but also that policymakers must increase their understanding of the models and how to interpret the results. Alm Ericson also asked the experts on the panel if they believed a development towards more consensuses on the conclusions drawn from the models could be expected. Can we expect something similar to an international agreement on climate economics?

Måns Nilsson commented that one way to reach more consensuses is to do more ex-post and econometric analysis. Germany and the Nordic countries have implemented a lot of policies and more econometric analysis is required to understand if their economies have suffered in terms of growth, employments and social aspects. He mentioned the feed-in tariff system in Germany. How much have the Germans suffered from this policy measure?

Conny Olovsson replied by highlighting that we should not expect consensus. The costs are distributed across the globe unevenly.

Questions from the audience

Viveka Palm KTH/Statistics Sweden wondered how often the results are also the assumptions of the model?

Conny Olovsson answered that models are based on the assumptions and those should be very clear and transparent. The results should then be analysed and understood based on the model set up and assumptions. One also has the possibility to adjust the assumptions. He went on and said that there is not much disagreement among scientists about what policies to implement e.g. tax or other regulation. However, the cost of doing nothing with regards to climate change is highly uncertain and large disagreements exist among those that develop models to analyse this area.

Tiina Koljonen explained how researchers also question their results sometimes. The questions posed are the key and mistakes in model set-up or in assumptions can deliver strange results. It is a fairly long process to get it all right. She also mentioned that the technological development that is the result of a model is not always possible to achieve according to the physics or science. Here you need physics and chemical experts to determine what is actually possible. A substantial amount of international collaboration exists globally to develop the appropriate models. Sometimes the constraints in the model are not known or the assumptions are irrelevant for some analysis. The path to emission reduction differs globally, but there is a general consensus on what needs to be done. Some countries focus on renewable energies others on technologies such as SSC.

Shardul Agrawala said that policy conclusions do sometimes come from assumptions. Then there is a need to be transparent and carry out sensitivity analysis and relax the assumptions. It is also important with model comparisons. In engineering models the laws of physics define the equations, but that is not the case in economics. It is also much more interesting to get results from many models.

Magnus Nilsson, independent consultant, asked if we do not expect the wrong thing from models. Models cannot predict the future, for example in 2007/2008 the boom in oil prices was not expected and the allowance prices were determined accordingly. Models should rather be used to analyse what disruptive events mean and the possible developments of them. He also brought up the issue of the ETS and whether or not it has failed. The objective is to reach the set target at a low cost with low allowance prices. The set target is determined by politicians. The allowance price level discussion is a dead-end to me.

John Hassler said that there is no need for complicated model to say something about the optimal allowance price. You need a simple demand-supply model, where supply is fixed and demand is varying. He also said that he thought that the price is very important, due to the signal it sends.

Nick Macaluso mentioned that different baselines are often modeled to give a range rather than an *estimate.*

Leif Holmberg, Swedish EPA, asked Kristoffer Steen Andersen if he thought that there are shortcomings in the Swedish macro-economic model MIMER that incorporate technological change exogenously.

Kristoffer Steen Andersen replied that technological change can be modeled differently and that it is the question to be analysed that determines how technological development should be modeled. It is important to have an informed dialogue about it before deciding on the optimal method.

Nils Brown, KTH, asked about technological development and the feedback effects of negative climate effects and the propensity to invest.

John Hassler replied that uncertainty should be taken into account. Few IAMs can incorporate stochasticity, but our stylized model can take it in. Our results show that there is no great impact of uncertainty. We do however abstain from catastrophic non-linearities in the model. Tail probabilities are difficult to quantify. Modern macro-economic models incorporate stochastics, but IAMs are generally old style macro-economic models that do not include stochastics.

Brita Bye underlined that IAMs are much aggregated models. Too complex to get thresholds in these models, hence that is left to macro-economists and they use an engineering type of structure in their macro-models.

Shardul Agrawala highlighted that there is a large need for more information regarding risks and the probabilities of certain events/thresholds etc and also their physical impacts. This information must come from the physical science.

Elisa Abascal Reyes, Swedish EPA, stressed the need to distinguish between climate policy impact and climate impact and also understand the long versus short term impacts. She took the example of inflation and monetary policy, where consumption boosting has in some countries been a policy path to raise inflation. When that is done, the amount of emissions are increasing as well, how is that seen upon?

John Hassler replied that monetary policy gives in particular short-run effects to the economy. The deviation from the long-run trend is hence minor. Climate models care about the long-term effects in particular and hence the short-run impacts are less important to model. He also stressed that monetary policy is sometimes expansionary and other times contradictionary and in the long run these effects should cancel out.

Conny Olovsson, mentioned that the bank of England have started talking about climate change and the economic effect. This is more related to financial stability and effects on insurance companies etc.

Martin Ådahl asked about the Nordic countries, which are small countries and want to be fore-runners in the fight against climate change. He particularly asked about the potential carbon leakage in this respect.

Tiina Koljonen brought up the Nordic energy technology prospective study to remind about Nordic cooperation. This report had just been launched. It focused on urban issues.

Ola Alterå mentioned that the Nordic countries have a common electricity market. Different policy tools can be compared and evaluated across the Nordic countries. To do nothing on climate change is the most expensive, hence we must find good policy measures.

Concluding remarks

Bert Saveyn concluded the whole conference. He started off by informing the audience that models are used widely as a guide to policy making, by countries, organisations (OECD, IMF, FAO, World Bank), institutions (IPCC, Stern review), universities and research institutes, consultancies and to inform trade negotiations and central banks. Bert Saveyn said that each important policy initiative taken by the European Commission has to be accompanied by an Impact Assessment (IA) that evaluates the potential economic, social and environmental consequences of that policy. This work involves modeling and examples of recent IAs are related to the conclusions from the Conference Of the Parties (COP) to the UNFCCC (United Nations Framework Convention on Climate Change) meeting in Paris 2015; the 2030 EU Climate and Energy Framework; the EU Clean Air Package 2013 and the EU Energy and Climate Trends (reference scenario). The IAs are scrutinized by the Regulatory Scrutiny Board, which provides a central quality control and support function for the Commission's impact assessment and evaluation work.

The questions that the different models can answer are often divided into short term, policy implementation, or long term analyses. The short-term questions could for example be:

- What are the consequences for individual member states of a specific burden sharing agreement? How large is the risk of carbon leakage and in what sectors are the risks highest? What are the implications on competitiveness of introducing a specific policy?
- What are the consequences on the ETS and non-ETS sectors of a specific emission reduction target or a specific policy measure? What do sectoral targets imply for the sector and for the economy as a whole? What are the implications on employment of a specific emission reduction target or measure?
- What is the optimal policy instrument, where the discussion often focus on prices versus quantities i.e. should we have a carbon tax or an emission trading system?
- What does a specific policy mean for energy security? What are the implications of fossil fuel subsidies on the economy and on the competitiveness of renewables? What does R&D support imply for sectors and the economy, when relative prices changes?

The important long-term questions relate to the impacts of a policy proposal on the following areas:

- Emission profiles
- Temperature increase
- Climate damages
- Oil/Resource supply and prices
- Economic growth and technological progress

The main modelling challenges, which are under continuous discussion in order to be overcome, relate to issues such as structural/disruptive changes. This includes, but is not limited to, technological breakthroughs, extreme events such as those with a long fat tail distribution[2], tipping points and uncertainty.

Furthermore, on-going discussion are held regarding the optimality of using GDP as the main unit for measuring impacts or if that should be complemented with other units or indices. Discussions are also held in the modelling community regarding how non-market impacts such as those on biodiversity and equity

[2] A probability distribution with fat tails would be one in which moderately extreme outcomes were more likely than in a situation with a normal distribution. In terms of climate change, some well-known economists like William Nordhaus discuss the need to use a damage function with a fat tail distribution. In that case a fat tail is considered undesirable because of the additional risk it implies in terms of more severe damages related to climate change.

can be incorporated into the modelling framework. Finally, how can non-rational behaviour be modelled when the basis of economic modelling says that humans act rationally?

There are many different types of models. These are generally classified into Computable General Equilibrium (CGE) models, energy system models, Integrated Assessment Models (IAM) and macroeconomic models.

The CGE models are built with a top-down approach and are multi-sectoral and aggregate in nature. These models are often global, but can also be country specific. They are data intensive and rely on (global) input-output tables. They are used to analyse issues related to energy, climate, air quality, but also trade and agriculture. They can be used in answering questions as those explained above and related to carbon leakage, competitiveness, tax versus free allocation of emission allowances, distribution of impacts across sectors and countries, employment, burden sharing, etc. The most well-know CGE models that have linkages to the environment are GEM-E3, Worldscan, Mirage, EPPA, SIC-GEM, GTAP family and national models.

The energy system models are, in opposition to CGE models, partial equilibrium. They hence focus on a single, or a group of, sectors such as the energy intensive industries and the energy sector itself. These models are also global or country specific, bottom-up, engineering models. They can answer questions related to sectoral impacts and the kind of technology deployment i.e. renewables versus fossil fuels. The most well-known energy sector models are PRIMES, POLES, POTEnCIA, GAINS, TIMES/MARKAL/TIAM family, CAPRI, NEMS.

Macroeconomic models are of a different kind compared to those model classifications just outlined. In terms of modelling climate change impacts, they are today not very useful. Instead they focus on a single sector or a number of limited sectors in a single country. They are often so called endogenous growth models, based on the theoretical work of Robert Solow and nowadays sometimes incorporate aspects of the work by Roemer[3]. They have an important role for technological growth analysis in the context of energy and climate. They are much more aggregated and top down than the other models. To the classification of models, there are also so called micro-simulation models that can for example assess equity and finally there are econometric models.

Bert Saveyn stressed that there is no super model that can tell the full truth. Neither is it sufficient to only use one type of model. Experts and researchers should rather use a modelling tool box, a *"Suite of models"* for analysing the issue at stake. There are hybrid models and in the field discussed at this conference they are often called E3 models, which stand for economy, energy and environment models. Generally, a soft link approached is used to connect models such as energy system model(s) and a CGE model. That can be used for short-term policy implementation questions such as tax, burden sharing, etc.

There is also the group of models called Integrated Assessment Models (IAM). They are very long-term with aggregated insights of complex processes. They are linked with bio-physical models, which analyse weather, sea level, crop, floods. Cross boundary issues such as air quality, poverty, social, and biodiversity issues are complex to model and sometimes need to be complemented with research from other fields of

[3] Roemer has among other things elaborated on a formal theory of sustainability, which he and his peers have applied to the problem of climate change (Llavador, Roemer, and Silvestre 2010 and 2011). Rather than maximizing a sum of discounted generational utilities into the future, which is the common practice of economists working on climate change, the authors maximize an objective which sustains welfare at the highest feasible level, or sustains growth in welfare at a chosen growth rate.

studies. Similarly, some issues are complemented with research from the political science field, for example behavioural economics issues that analyse non-rationality.

Bert Saveyn said *"models simplify reality, they are supposed to do so and that is a feature rather than a bug*. Furthermore, he said that models are not *"a silver bullet"* neither a *"crystal ball"*. However, they are a way to structure the debate, to narrow down the problem to the fundamentals. They are also a driver to harmonize facts and data across the stakeholders. Furthermore, they are trust building in international climate diplomacy and a way to compare policy options in a rigorous manner. For example they can analyse imperfect, 2nd best policies versus 1st best, perfect policies and highlight "trade-offs" in societies. They are also a way to introduce "policy coherence" across policy departments.

Bert saveyn stressed that one should be humble towards the use of models. It is necessary to manage expectations, implying that there need to be a good interaction and mutual understanding between modellers and policy stakeholders to build up long-term credibility. The results should be neutral/scientific in nature and there should be transparency of the assumptions, limitations and the constraints introduced in the model. The interpretation of the results should not be overstretched. The results are not necessarily *"accurate",* but should be *"robust"*, hence they should show the "*mechanisms"*.

Finally, Bert Saveyn ended the conference by saying that modellers have a very specific profile. To become a modeller is a long-term investment and there need to be a critical mass of them in order to assess and criticise the outcome of their work. There is also a need for detailed sectoral knowledge such as of the energy intensive sectors and Land Use, Land Use Change and Forestry (LULUCF). It is also vital to have people with different theoretical backgrounds when setting up and develop models, especially engineers (for the energy system models) and economists, etc.

Sammanfattning

Den Nordiska konferensen om ekonomiska modeller och deras policyrelevans, i klimathänseende, hölls 25 maj 2016 i Stockholm. Talare var experter och forskare från OECD, svenska universitet och nordiska institutioner samt politiker från olika politiska partier i Sverige och Finland.

Målet med konferensen var att diskutera hur man bättre integrerar klimatfrågorna i ekonomisk politik, när makroekonomiska modeller sällan kan ta hänsyn till klimataspekter på grund av tekniska svårigheter i uppbyggnaden av dessa modeller. Diskussionen fokuserade på möjligheter och begränsningar i olika sorters ekonomiska modeller samt olika klimatpolicy-frågor. Den övergripande slutsatsen av konferensen var att det troligtvis inte är möjligt på kort sikt att ta in klimataspekterna i makroekonomiska modeller. Under diskussionerna blev det istället uppenbart att man behöver ha en rad olika sorters modeller för att analysera olika frågor. Det blev därmed tydligt att alla frågor inte kan täckas in av en och samma modell, vanligtvis delar man upp frågor på kort- och lång sikt och använder partiella (sektorsmodeller) och/eller allmänjämvikt (ekonomiövergripande) analyser där val av modell beror på frågeställningen som ska besvaras.

En stor del av diskussionen handlade om vad ekonomiska modeller är ämnade för. Det poängterades då att modeller inte är lämpade för att ge resultat i form av en siffra som visar vad kostnaden i framtiden blir, utan att de snarare kan ge underlag till vilka mekanismer som verkar var och när. Med andra ord visar modellerna snarare på samband som kan vara värdefulla när man utvecklar politiken och bör visa sina resultat i form av framtida scenarier, snarare än begränsade prognoser. I slutsatserna sades att *”modeller förenklar verkligheten, det är själva poängen med modellerna och är därmed inte en felkonstruktion”.* Modellerna är till för att strukturera debatten och koka ner problemet till det mest fundamentala. Rätt uppbyggda och använda, är modeller också förtroendegivande i internationell diplomati och ett sätt att jämföra policyförslag på ett rigoröst sätt. Vidare bör man beakta resultat från flera modeller för att få ett så bra beslutsunderlag som möjligt.

Det var tydligt att det finns ett kontinuerligt behov av att utveckla modeller och att använda flera sorters modeller för att ge så bra underlag till politiken som möjligt. De stora framtida utmaningarna ligger i att modellera teknisk utveckling, plötsliga och extrema händelser, tipping points, och att ta hänsyn till olika sorters osäkerheter i modellerna (här behövs bättre kunskaper inom framförallt naturvetenskapen om olika frågor såsom hur temperaturökningar påverkar vårt klimat).

När det gäller policyfrågor var det mer eller mindre full konsensus att en global koldioxidskatt är det optimala verktyget för att få ner utsläppen på ett kostnadseffektivt sätt. Mycket kritik framfördes om EU ETS, vilket inbegrep överallokering av utsläppsrätter och det låga priset på rätterna, samt problemet med att additionella styrmedel inte får någon positiv miljöpåverkan med ett handelssystem då utsläppen bara flyttar inom systemet. Handelssystem tycks trots detta vara vad andra länder utanför EU också vill ha. Ett viktigt problem som uppstår med ett handelssystem är att politiker riskerar att sätta ett för högt mål efter påtryckningar, med en tillhörande generös tilldelning av utsläppsrätter, vilket leder till en minimal positiv miljöeffekt i slutändan. Denna problematik bör ses över för att få fungerande handelssystem

Appendix 1. Conference program

Nordic conference on climate-economic and macroeconomic models and their policy relevance

08.30 – 09.00	**Registration and coffee**
09.00 – 09.15	**Welcome and introduction** *Björn Risinger, Director General of the Swedish Environmental Protection Agency;* *Fredrik Granath, Chairman of the Environment and Economy Group, Nordic Council of Ministers;* *Martin Ådahl, Moderator*
09.15 – 09.45	**Macroeconomic models and policymaking** *Speakers: Thomas Eisensee (Ministry of Finance, Sweden), Brita Bye (Statistics Norway), Kristoffer Steen Andersen (Danish Energy Agency)*
09.45 – 10.15	**Climate-economic models and policy challenges** *Speakers: John Hassler (Swedish Council of Fiscal Policy/Stockholm University), Tiina Koljonen (VTT Technical Research Center Finland), Kristoffer Steen Andersen (Danish Energy Agency)*
10.15 – 10.30	**Coffee break**
10.30 – 10.45	**Thomas Sterner: comments on the previous presentations and recommendations for future work**
10.45 – 11.30	**The economic consequences of climate change: insights from the OECD CIRCLE project** *Rob Dellink, Coordinator Modelling and Outlooks, Environment and Economy Integration Division, OECD Environment Directorate* **Mainstreaming climate change considerations in economic and sectoral policymaking** *Shardul Agrawala, Head, Environment and Economy Integration Division, OECD Environment Directorate*

11.30 – 12.00 **Introduction to the hearing and presentation of the panellists**
<u>Politicians:</u> Jonas Jacobsson Gjörtler, The Conservatives; Monica Green, The Social Democratic Party; Rasums Ling, The Green Party; Lars Tysklind, The Liberal Party; Satu Hassi, The Green Party Finland.

<u>Researchers and experts:</u> Thomas Sterner, University of Gothenburg; Conny Olovsson, The Riksbank; Måns Nilsson, Stockholm Environment Institute; Ola Alterå, Sustainable Innovation; Anders Wijkman, Committee on Environmental Objectives; Nick Macaluso, Environment and Climate Change Canada and previous speakers.

12.00 – 13.00 **Lunch**

13.00 – 15.00 **Hearing: economic models and their policy relevance**
Three sessions with the following focus:
- *Research (35 minutes)*
- *Policy (45 minutes)*
- *International cooperation (25 minutes)*

15.00 – 15.30 **Coffee break**

15.30 – 16.15 **Questions from the audience**

16.15 - 16.40 **Can we make climate-economic and macroeconomic models more policy relevant?**
Bert Saveyn, European Commission Joint Research Centre

16.40 - 16.50 **Final note: Kristina Persson, Minister for Strategic Development and Nordic Cooperation, Sweden**

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Appendix 2. Speakers at the conference

Moderator

The conference was moderated by Mr. **Martin Ådahl**, chief economist at the Swedish Centre Party. He has previously worked as a senior economist at the Swedish Riksbank and he was also the co-founder and chief editor of the Swedish magazine "Focus". Martin Ådahl has also been the CEO of the Swedish green liberal think tank FORES.

OECD experts

Shardul Agrawala is Head of the Environment and Economy Integration Division at the OECD Environment Directorate. In this capacity since 2013, Dr. Agrawala leads the Directorate's work on economic-environmental modelling, empirical analysis of environmental policies, trade and environment, and on resource productivity and waste. He is also Co-Chair of the Research Committee on Inclusiveness for the Green Growth Knowledge Platform (GGKP). At the OECD since 2002, Dr. Agrawala has previously served as Senior Advisor to the OECD Secretary General, Co-ordinator of the OECD-wide initiative on New Approaches to Economic Challenges, Acting Head of the Climate Change Biodiversity and Development Division, and Senior Economist Climate Change. Dr. Agrawala has published extensively on climate change. He has led teams of international experts as Coordinating Lead Author for chapters of the Fourth and Fifth Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC). He has testified before the US Congress, contributed to the Stern Review, and served on advisory panels for the Pilot Program on Climate Resilience of the World Bank and the International Climate Initiative (ICI) of the German Government. Dr Agrawala received his PhD from Princeton University and has previously held research positions at Princeton University, Harvard University, Columbia University and at the International Institute of Applied Systems Analysis (IIASA).

Rob Dellink is the Co-ordinator Modelling and Outlooks at the Environment and Economy Integration Division of the OECD Environment Directorate. In this capacity, dr. Dellink leads the Directorate's work on economic-environmental modelling and long-term outlooks. He joined the OECD in 2009 and has been working on long-term environmental-economic projections, not least the future costs of climate change mitigation and adaptation policies. He was also a lead author of several chapters of the OECD Environmental Outlook to 2050. He currently co-ordinates the work on the CIRCLE project, which aims to assess the costs of inaction on climate change, air pollution, and the land-water-energy nexus. Before joining the OECD, dr. Dellink worked as a senior researcher and lecturer at the VU University Amsterdam and Wageningen University, both in the Netherlands. He published extensively on a wide range on environmental-economic topics. He holds a PhD in economics from VU University Amsterdam and a Masters in econometrics from Tilburg University (The Netherlands).

Researchers and experts

Ola Alterå is former State Secretary at the Swedish Ministry of Enterprise, Energy and Communication, and former UNIDO (United Nations Industrial Development Organization) Representative in Kenya. Former appointments also include a position at the Department of Environmental Economics at the Swedish Environmental Protection Agency. Today, Alterå is CEO of Sustainable Innovation and leading a governmental inquiry regarding policy measures to stimulare a circular economy.

Brita Bye, PhD in Economics, University of Oslo is a senior research fellow at the research department at Statistics Norway and a member of the management group of CREE (Oslo Centre for Research on Environmentally friendly Energy). Main research interests are economic growth, public economics and energy- and environmental economics. Most of the research has been related to normative policy analyses in a range of fields including environmental policies and growth policies. The research is mainly based on analyses that develop and utilize numerical general equilibrium models. Member of several governmental expert committees, including the Norwegian Ministry of Finance's Green Tax Commission in 2015, currently a member of the Ministry's advisory committee for Model and Methodological issues.

Thomas Eisensee is a Senior Advisor at the Swedish Ministry of Finance and holds a PhD in economics from the Institute for International Economic Studies at Stockholm University. He has previously worked at the Swedish Fiscal Policy Council, at the Royal Danish Embassy in Stockholm and has been a Visiting Researcher at the University of Rochester in New York. Thomas has been responsible for developing the long-term macroeconomic model MIMER at the Swedish Ministry of Finance.

John Hassler is Professor of Economics at the Institute for International Economic Studies at Stockholm University where he also is Deputy Director since January 2015. John Hassler obtained his Ph.D. in Economics from MIT. He has been teaching subsequently at the Stockholm University. His research has covered areas of dynamic public finance, social mobility, growth and climate change. Since December 2009, he is serving as a member of the Prize Committee for the Prize in Economic Sciences in Memory of Alfred Nobel. He is also the Chairman of the Swedish Fiscal Policy Council, in charge of evaluating the government's economic policy. He worked as advisor to the Swedish Ministry of Finance during the recent financial crisis when he was also a member of the European Economic Advisory Group. He is currently a member of the Bellagio group of academics and central bankers. His current research covers Global warming and long run economic growth, dynamic political economy of government (in particular redistribution, social security and health) and optimal taxation and social insurance.

Tiina Koljonen is a Research Team Leader of Energy Systems research at VTT Technical Research Centre of Finland. She has above twenty years' experience in developing and analysing future energy markets, systems and clean energy technologies on a national, Nordic, EU, and global levels. She has supported Finnish government and the EU in formulating and analysing effective energy, climate, and innovation strategies and policies. She has also coordinated several national and international projects focusing on integrating roadmap processes and transition management to energy scenario and business analysis. Recently, she co-ordinated a multi-disciplinary platform for transforming Finland to a low carbon society. This platform directly supported the Finnish government in creating a Low Carbon Roadmap for 2050 for Finland. Currently she supports the Finnish Government in formulating new energy and climate strategies up to 2030 for Finland.

Nick Macaluso is the Director of the Model Development and Quantitative Research Division, Economic Analysis Directorate within the Strategic Policy Branch of Environment and Climate Change Canada. He has worked on energy, environment and economic emissions for some 30-years. Prior to joining

Environment and Climate Change Canada, Nick worked at Natural Resources Canada on issues related to energy efficiency, R&D and energy projection. Nick is currently responsible for the development and implementation of economically sound analytical frameworks and methodologies used to analyze the interaction of energy, economic and environmental issues and ultimately provide sound and robust economic advice. He oversees the use and development of a variety of analytical tools, including an international and Canadian multi-region, multi-sector recursive computable general equilibrium international model, a global integrated assessment model, and a detail Keynesian-based macroeconomic model for Canada. These tools are used for developing integrated energy, emissions and economic projections and for supporting the developing of climate change and clean air policies.

Måns Nilsson is Research Director and Deputy Director at Stockholm Environment Institute (SEI) and part time Professor of the Practice of Environmental Strategies and Policy Analysis at the KTH Royal Institute of Technology. Key areas of interest are in low carbon energy and transport policies, development studies and the 2030 agenda, innovation and transitions, and institutions and governance. Måns combines academic achievement with extensive management experience. As Research Director he oversees SEI's global research leadership and has fostered the development of its strategic initiatives and its academic cooperation agreements. In recent years he helped establish the Global Commission on the Economy and Climate and has been closely involved as an advisor to the UN, OECD and the European Commission on the Sustainable Development Goals. He is a member of the Scientific Council for Sustainable Development to the Government of Sweden. Måns has slipped more than 40 papers past unsuspecting editors of academic journals and has edited two books. He received his MSc in International Economics from University of Lund, Sweden, and his PhD degree in Policy Analysis from Delft University of Technology, Netherlands.

Conny Olovsson is Senior Economist at the Monetary Policy Department Research Division of the Riksbank. Conny Olovsson obtained his PhD from Stockholm University in 2004. Prior to joining the Research Department of Sveriges Riksbank in 2013, he was a postdoc at the Stockholm School of Economics (2004-2008), and a visiting researcher at the Institute for International Economic Studies in Stockholm (2008-2013). Conny Olovsson's research interests include public finance, asset pricing, economic growth and climate economics.

Bert Saveyn is a researcher at the European Commission's Joint Research Centre (JRC). Bert Saveyn holds a Master degree in Environmental Engineering (2000) and a PhD in Environmental Economics (2007) from the University of Leuven. In 2004, he was a visiting researcher to ZEW, Mannheim. He joined the European Commission in 2007. At the JRC he deals with the economic analysis of climate and energy policies. More particularly, he uses the macro-economic model GEM-E3 for policy support to various Directorates-General (DG), and has contributed to the Impact Assessments of DG Climate Action, Energy and Environment. He has also worked on green taxation for DG for Economic and Financial Affairs and Taxation and Customs Union. Recently, he was involved in the "Road to Paris" Communication on the COP21 negotiations in Paris, the Impact Assessment of the "2030 Framework on Climate and Energy Policies", and the Impact Assessment of "The Clean Air Policy Package". Since 2014, he is an Advisory Board Representative in the Global Trade Analysis Project (GTAP) Consortium.

Kristoffer Steen Andersen is an advisor at the Danish Energy Agency since 2011 and is currently working on achieving a PhD in the area of Integrated Energy and Macroeconomic Modelling. He is an Environmental Economist by training with a background in economic and technical modelling of energy systems. His working experience at the Danish Energy Agency includes analysis related to energy forecasts and developing methods for socio-economic assessment.

Thomas Sterner is Professor of environmental economics at the University of Gothenburg. For the academic year 2015-2016 he has been elected as a visiting professor at the Collège de France. In 2012-2013 he was on sabbatical leave from the University of Gothenburg and worked as Chief Economist at the Environmental Defense Fund (EDF). His main areas of work at the EDF were, among other things, related to instrument design for climate policy and catch shares in fisheries. Thomas Sterner has published about 100 articles in refereed journals, authored or edited more than a dozen books and a large number of book chapters, official reports and journal articles. The main focus of his work has been on environmental policy instruments with applications to energy and climate, industry, transport economics and finally resource management in developing countries. He was a member of the Scientific Council for Sustainable Development to the Swedish Government 2015- (Miljövårdsberedningen/Vetenskapliga Rådet för Hållbar Utveckling), Chairman FORES scientific panel for the environment, 2015 and Coordinating Lead Author for the IPCC AR5 2010-2015.

Anders Wijkman is the Chair of the All Party Committee of the Environmental Objectives. He has also been a member of the Swedish Parliament 1971–78, Secretary General of the Swedish Red Cross 1979–88 Secretary General, Swedish Society for Nature Conservation 1989–91 Director General, Swedish Agency for Research Cooperation with Developing Countries 1992–94 Assistant Secretary General of the United Nations and Policy Director, UNDP 1995–97 Ambassador, Swedish Foreign Ministry 1998, member of the European Parliament 1999–2009, Senior Advisor at Stockholm Environment Institute (SEI) and Linköping University 2010–. Among his current international commissions are vice president of the Club of Rome since 2007, Board Member of the World Resources Forum Association from 2012, Member of the Advisory Council of the European Climate Foundation 2008, Member of the World Academy of Arts and Sciences since 1998. From 2001 to 2009 Chairman of the Board of Globe EU, a network of parliamentarians in favour of strong and proactive environment, conservation and climate policies. Other activities include author of several books on disaster prevention, sustainable development, HIV/AIDS and Resource efficiency. In August 2012 the book "Bankrupting Nature" was launched. The book was co-authored with Professor Johan Rockström, SEI. Awards Technology Doctor, h c, Linköping University 2011.

Politicians

Members from the National Parliaments of the Nordic countries were invited to join the panel at the hearing. The following MPs contributed:

Satu Hassi is Chair of the Committee on Environment of the Finnish Parliament for the Green Party.

Janine Alm Ericson is a Member of the Committee on Finance of the Swedish Parliament for the Green Party.

Monica Green is Member of the Committee on Finance of the Swedish Parliament for the Social democratic Party.

Jonas Jacobsson Gjörtler is Member of the Committee on Environment and Agriculture of the Swedish Parliament for the Conservative Party.

Lars Tysklind is Member of the Committee on Environment and Agriculture for the Liberal Party.

Appendix 3. Participants at the conference

Name of participant	Organisation
Allan Gustafsson	Mapsec
Amanda Stefansdotter	Copenhagen Economics
Anders Wijkman	Committee on Environmental Objectives
Anne-Cerise Nilsson	Government Offices of Sweden
Annelie Lundgren	Finansinspektionen
Bert Saveyn	European Commission
Björn Risinger	Swedish Environmental Protection Agency
Brita Bye	Statistics Norway
Charlotte Berg	National Institute of Economic Research
Conny Olovsson	The Riksbank
Dag Henning	Swedish Environmental Protection Agency
Elena Dawkins	Stockholm Environment Institute
Eli Marie Naess	Norwegian ministry of climate and environment
Elisa Abascal Reyes	Swedish Environmental Protection Agency
Elisa Lanzi	OECD
Elly-Ann Lindström	Government Offices of Sweden
Elsa Krantz	The Center Party
Emma Thornberg	Swedish Energy Agency
Eva Alfredsson	Swedish Agency for Growth Policy Analysis
Evelina Linnros	Stockholm University
Fredrik Granath	Swedish Environmental Protection Agency
Fredrik Hannerz	Ministry of Environmnent and Energy, Sweden
Hans Hjortsberg	Swedish Environmental Protection Agency
Helen Ågren	Government Offices of Sweden
Helena Leander	Swedish Energy Agency
Ida Björk	Statistics Sweden
Jean Chateau	OECD
Jens Holm	The Left Party
Jesper Lindé	The Riksbank
Johan Lidman	Stockholm University
Johanna Farelius	Swedish Environmental Protection Agency
John Hassler	Swedish Fiscal Policy Council/Stockholm University
Jonas Jacobsson Gjörtler	The Conservative Party
Karl Hallding	Stockholm Environment Institute
Karl-Anders Stigzelius	Swedish Environmental Protection Agency
Katrin Zimmer	Swedish Environmental Protection Agency
Klara Sommerstein	Government Offices of Sweden
Klaus Hammes	Swedish Energy Agency
Kristian Skånberg	Stockholm Environment Institute
Kristina Persson	Minister, Strategic development & Nordic cooperation
Kristoffer Steen Andersen	Danish Energy Agency
Lars M Widell	Swedish Board of Agriculture
Lars Tysklind	The Liberal Party

Leif Holmberg	Swedish Environmental Protection Agency
Lena Unemo	Expert Group on Public Economics
Lina Isacs	KTH Royal Institute of Technology
Magnus Cederlöf	Ministry of Environmnent, Finland
Magnus Nilsson	Magnus Nilsson Produktion
Malin Lagerquist	Swedish Energy Agency
Malin Modh	Swedish Environmental Protection Agency
Marcus Carlsson Reich	Swedish Environmental Protection Agency
Marie Thorsbrink	Finansinspektionen
Marina Fransson	Ministry of Enterprise and Innovation, Sweden
Marit Widman	National Institute of Economic Research
Marita Laukkanen	VATT Institute for Economic Research
Martin Eriksson	Swedish Environmental Protection Agency
Martin Flack	Copenhagen Economics
Martin Ådahl	Moderator
Miriam Munnich Vass	Swedish Environmental Protection Agency
Monica Green	The Social Democratic Party
Monica Nelson Edberg	Statistics Sweden
Måns Nilsson	Stockholm Environment Institute
Nancy Steinbach	Statistics Sweden
Nannan Lundin	Prime Minister's Office
Nick Macaluso	Environment and Climate Change Canada
Nils Brown	KTH Royal Institute of Technology
Nils Westling	2050 Consulting AB
Ola Alterå	Sustainable Innovation
Oskar Larsson	Swedish Environmental Protection Agency
Pelle Boberg	Swedish Environmental Protection Agency
Pelle Magdalinski	Swedish Environmental Protection Agency
Per Klevnäs	Copenhagen Economics
Per Strömberg	Swedish Environmental Protection Agency
Peter Stigson	COWI
Philip Thörn	IVL Swedish Environmental Research Institute
Rasmus Ling	The Green Party
Rob Dellink	OECD
Roger Josefsson	Danske Bank
Sara Wärn	Stockholm University
Satu Hassi	Parliament of Finland
Shardul Agrawala	OECD
Stina Gustafsson	Government Offices of Sweden
Shyhrete Shala	Swedish Environmental Protection Agency
Søren Olsen	Ministry of Taxation, Denmark
Therése Karlsson	Government Offices of Sweden
Thomas Eisensee	Ministry of Finance, Sweden
Thomas Sterner	Gothenburg University
Tiina Koljonen	VTT Technical Research Centre of Finland

Tobias Persson	Swedish Agency for Growth Policy Analysis
Ulrika Stavlöt	FORES
Ulrika Svensson	Swedish Environmental Protection Agency
Viktor Gunnarsson	Ministry of Finance, Sweden
Viktor Löfvenberg	Swedish Environmental Protection Agency
Viveka Palm	Statistics Sweden