Integrating an input-output-model with an actor-orientated, technology based bottom-up approach to support clean air policy in Germany

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Abstract

Within the otello project a national integrated assessment model is developed to provide a tool for political decision makers in Germany to assess political instruments regarding their ecological and economic effects. There for a macroeconomic input-output model is coupled with technology based bottom-up models for the four emitter groups of industrial production, energy supply, transport and residential buildings. For the industry sub-model an actor-based approach was chosen that simulates investment decisions based on a multi-staged process description. This contribution describes the modelling approach of the industry sub-model using the example of the iron and steel sector and its integration into the input-output-model.

Introduction

In spite of large progress on this subject, air pollution still causes negative effects on human health and the environment. Additionally the problem of climate change makes it inevitable to mitigate greenhouse gas emissions. To reach the intended mitigation efficiently, it is necessary to make use of synergies arising from the simultaneous treatment of several pollutants and emission sources. Interdependencies in supply chains as well as mitigation potentials resulting from changes in consumer behaviour also have to be considered. The otello project aims to develop an integrated assessment model (IAM) for Germany to deliver decision support for political decision makers to design a national emission mitigation strategy. An IAM comprises the complex interdependencies between anthropogenic activities and their effects on ecosystems, and there for integrates the knowledge from different scientific disciplines.

The model regards the emissions of SO_x, NO_x, NH_3, dust and CO_2 from industrial production, energy supply, transport and residential buildings until the year 2030. To provide better decision support for the users political instruments are evaluated by a multi-criteria decision module that encompasses the different dimensions of sustainability.

Emissions are determined mainly from two factors: namely the activity rate and the emission factor. The activity rate reflects the frequency of an emitting process, in most cases it is given by the production rate. The emission factor describes the specific emissions per activity unit and is determined by the technology used in the process. Consequently to estimate the emissions of an economy it is necessary to regard both, its economic as well as its technological development. The economic development is simulated in otello via a macroeconomic input-output model (IOM) describing the interdependencies between different emitter groups and industrial sectors. It is connected with technology based bottom-up models for the emitter groups of industrial production, energy supply, transport and residential buildings. The main task of the sub-models is estimating emissions by simulating the anthropogenic activity in this field and the development and diffusion of relevant technology.
This article starts with a description of the macroeconomic input-output-model that constitutes the connection between the sub-models. Afterwards the modelling approach of the industry model and its integration into the IOM are described using the example of the iron and steel sector.

Description of the input-output-model

The IOM simulates the economic development and calculates the macroeconomic parameters that are used by the sub-models and thereby ensures the consistency of the results.
The basis of the IOM is the national input-output table published by the German federal statistical office [1]. This table includes supply relationships between all sectors of the economy and enables the calculation of the total demand from final demand. Further it is possible to derive the matrix of technical coefficients, that describes the average production technology of each sector as a kind of "cooking recipe" [2]. In otello 65 sectors are distinguished. The sectors of energy supply were subdivided based on data from environmental accounting [3] to simulate the use of 14 different energy carriers.
As consumption levels are important drivers for emissions, the consumption of private households is modelled endogenously by a linear expenditure system. Private consumption depends on the one hand on the income of private households that is calculated based on production rates from the industry. On the other hand changes in prices resulting from the industry sub-model are fed back and reactions of consumers are estimated. The private consumption of fuels for heating or private transport is calculated within the two sub-models for residential buildings and transport. Thereby, effects of changes in consumer behaviour on industrial production and the corresponding emissions

(e.g. fuel switching for space heating) can be included in the model. Further on, it is possible to aggregate effects resulting from the detailed sub-models at a national scale, which enables us to estimate the influence on economic indicators, such as GDP or employment.

Description of the industry sub-model

The industry sub-model comprises selected industry sectors with high contribution to Germany's overall emissions. For these sectors the emissions are calculated based on a detailed simulation of the currently and prospectively used technology for production and emission mitigation.

The diffusion of emission abatement measures results in reality from many individual decisions of the concerned actors. Therefore an actor-based approach is followed; this means individual plants and their decisions are modelled subject to their individual production technology.

For that purpose multi-stage reference processes are defined that represent the technical process steps of a technology, based on data from EGTEI[1] [4], BAT-Reference Documents [5] and sector specific literature [6]. For each process step an installation with emission factors for each pollutant and input-coefficients according to the 65 sectors of the IOM is defined. For the sector of iron and steel two reference processes are defined: the steel production in integrated steelworks and via Electric Arc Furnace (EAF). For the integrated steelworks six process steps are distinguished: sinter plant, coke oven plant, hot stoves (cowpers), blast furnace, basic oxygen furnace and casting. The production in electric steelworks takes place in two steps: EAF and casting.

The installations of upstream process steps produce intermediate goods (e.g. sinter), that are used as an input for the next process step (in this case the blast furnace). Emissions are calculated separately for each installation, differentiated into combustion or process related emissions and simultaneously for all pollutants. The combustion related emissions result from the fuel mix used, which is the reason to includes ten further energy carriers like blast furnace gas or coke oven gas in addition to the 14 energy carriers from the IOM. The multi-stage approach makes it possible to model not only additive but also integrative mitigation measures. Additive (end-of-pipe) measures reduce emissions according to their mitigation efficiency after their formation. They are modelled as a correction after the calculation of the emissions. In contrast process integrated measures avoid the formation of emissions and therefore are modelled by changing emission factors and input-coefficients of the installations. For example the direct injection of coal to substitute coke in the blast furnace process

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does not only reduce the emissions of the blast furnace itself but changes the quantity of coke to be produced and thus the emissions of the coke oven. Mitigation measures may have effects on more than one pollutant, these multi-pollutant effects are considered by simulating the change of all emission factors simultaneously.

The model uses information about location and technology of real plants to have an idea about the spatial distribution of the emissions. Based on data from the European Pollutant Emission Register (EPER) assumptions about the technical configuration of the individual plants are formulated for the base year 2001.

The further development of the technical parameters is driven by investments of single plants in mitigation measures and the modernization of existing machinery. The investment decision is modelled by the assessment of all feasible mitigation measures using the discounted cash flow method. To calculate the cash flow of future periods price and demand expectancies derived from economic parameters given by the input-output-model are used. Furthermore eco-political instruments are considered. Legal restraints like emission limit values force the plants to make an investment if they not yet meet the standards. In contrast fiscal instruments enter into the assessment either directly as a separate cost factor, e.g. emission trading certificates, or indirectly by influencing the cost- and demand structure of the plant. Thus, the eco-taxes on fuels constitute a price increase and offers incentives for fuel substitution.

By integrating the industry model into the IOM, changes in the average technology of a sector lead to an evolution of the input-output-matrix and effects on the cost and demand structure of other sectors become visible. So it is also possible to evaluate effects of instruments from other emitter groups (e.g. a decrease of energy demand after promotion of insulation measures in residential buildings) for different steps of the industrial value chain.

Conclusion

The described model provides decision support for the design of a national emission mitigation strategy by simulating the economic and technical development in Germany under different eco-political conditions. It is characterized by the interconnection of macroeconomic modelling with detailed technology based bottom-up approaches. It allows not only for the explicit simulation of process integrated mitigation measures but also demonstrates the potential of behavioural changes on consumer side. The assessment of political instruments considers interdependencies between pollutants and polluters and reflects both, consequences for individuals and aggregated effects on a macroeconomic level.

Annotations

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