MUTUALLY LINKING BOTTOM-UP ENERGY DEMAND MODELS WITH MACROECONOMIC MODELS – DEALING WITH INTER- AND INTRA-SECTORAL STRUCTURAL CHANGE

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Overview

Energy demand and supply projections for a country are generally based on two types of models: macroeconomic models (e.g. general equilibrium models, econometric models) and bottom-up models for several sectors (e.g. final energy demand sectors, the energy conversion sector). Both types of models are essential for future energy policy design and ex ante evaluation of energy and material efficiency strategies; however, both types have their strengths and limitations (Herbst et al. 2012b). In the recent past, an increasing trend to hybrid energy model systems in the energy modelling community has become apparent, linking both model types and running them iteratively. This idea is not new (Hourcade et al. (2006) ,Bataille (2005), EIA (2011; 2012), Jochem et al. (2007; 2008), Schade et al. (2009), Catenazzi 2009, Kumbaroglu and Madlener (2001), Capros et al. (1996a; 1996b), CES (2008), E3Mlab (2007)), but the progress on realising it in order to benefit from their strengths and avoid their limitations is a challenge. Problems can arise, as macroeconomic models deliver economic variables as results and bottom-up models need physical quantities (e.g. tonnes of steel, number of employees, or square meters) as inputs for their model runs. These physical drivers and their accuracy are of crucial importance concerning the quality of results in energy demand modelling. In addition, structural changes within the economy significantly affect energy demand of the economy: in highly industrialised countries energy intensity is reduced by these changes, or in emerging countries energy intensity may increase due to fast growing energy intensive basic goods industries. Therefore, this important driver has to be adequately considered in energy demand scenarios. Bottom-up models with their detailed representation of the technological structure of industries and the service sector require a number of economic and physical drivers as input, which generally demands to consider structural changes within branches (intra-industrial structural change) or among industrial sectors (inter-industrial structural change). The challenge, however, is to take consistent assumptions across the various model input parameters.

Methods

In this paper, we present a work in progress methodology to develop input parameters for the bottom-up models including consistent assumptions on the dynamics and development of structural changes. Such a methodology not only ensures that scenarios are based on a consistent set of assumptions, they also allow to use the strengths of bottom-up models to analyse technical and economic implications of the scenarios together. The methodology developed distinguishes three levels of analysis on which structural change is considered. These are briefly described in the following. First, future economic projections of a country often only start with the information on the national Gross Domestic Product (GDP) and the development of the population. A break-down of the aggregated GDP to the service sector, manufacturing industry, the construction and energy sector as well as the agricultural sector is often not available, but required as input into bottom-up models. Lacking results of a macro-economic model, such disaggregation is often done by trend extrapolation or estimates, but not in a transparent way taking into account influences like foreign trade, changes in international competitiveness, or national natural resources. Secondly, structural change also takes place within the economic sectors such as the manufacturing industry, where the gross value added of basic industries in highly industrialised countries may stagnate or even decline due to decreasing competitiveness, while investment goods industries tend to grow faster than the industrial average. Again, this accounting of inter-industrial structural change is often done by trend extrapolation or expert estimates. Thirdly, even in the case a macro-economic model is used to deliver value added figures for individual industrial branches, bottom-up energy demand models require more detailed information on the drivers of energy services, of which one important example is the physical production of energy-intensive industrial bulk products in tonnes per year (e.g. steel, primary and secondary aluminium, cement, lime, bricks, pulp and paper, glass, ceramics, sugar, chlorine, ethylene, propylene, etc). There are energy demand bottom-up models which distinguish mere than 100 or 200 energy-intensive industrial processes; some of them may even produce the same product (e.g. chlorine). Thus, the question is not only, how the physical production is related to the value added of one industrial sector, but also how shifts between alternative processes used for one product take place and will continue in the future depending on technological trends and economic opportunities. The domestic production of those energy-intensive products directly depends on the domestic demand and net foreign trade. However, the drivers of subgroups of the products may be divers and inducing different directions (e.g. saturation of demand such as bottle glass, substitution processes among basic materials such as the substitution between steel/aluminium/plastics, increasing demand such as flat glass due to triple glazing and solar photovoltaic and thermal collectors). In addition, the material demand may change due to better material quality and lighter construction; raw materials input may change due to increasing recycling rates which may involve much less energy-intensive processes.

Results

The paper reports on some ongoing research in this complex area. It covers the two steps of disaggregation of the GDP (if no input from macro-economic models is available) and the transformation from value added to physical production of value added of energy-intensive branches of industry, giving two examples of a stagnating and an increasing production in the non-metallic minerals industry). The paper covers various methodological considerations to capture the complexity reducing the efforts of expert estimates and increasing quantitative relationships based on econometrics and other physical simulation methods. As result, the electricity demand of the French, German, and Italian industry is given, indicating the influence of production, of inter-industrial and intra-industrial structural change, and efficiency improvements. The paper also covers the aspect of re-introducing the additional investments and changing energy and other cost of policy scenarios of bottom up models to the corresponding macro-economic model.

Conclusions

Mutually linking bottom–up energy demand models with macroeconomic models is – and will be – a major challenge of interdisciplinary research teams. The progress expected for running realistic energy demand projections as well as for simultaneously analysing the economic impacts of energy policy scenarios will be substantial in the next few years. To secure realistic energy demand projections, plausible economic futures of the economies considered are the prerequisite of a reliable energy demand projection. In case, that results from macroeconomic models are not available; the concept of linear growth of the GDP per capita of industrialised countries (and long term projections of emerging countries) is a simple and effective method to keep the long term GDP development as major driver of energy demand in a plausible range of possible development. Even in cases of available results of macroeconomic models the method should be used as quick check. (The authors have identified unrealistic GDP growth projections for several countries in the past). Analysts also have to be aware that structural shifts on sector- but also on industry-level should not be neglected in the energy modelling framework and do need more effort, if no macroeconomic model is available, than just trend extrapolation or expert estimates to provide transparent and comprehensive model results. The case studies represented above showed, that the influence of inter-sectoral structural change on final energy consumption within the last decades has led to an observable decrease in energy demand for Germany, France, and the United Kingdom. The results have lead to the conclusion, that especially countries, which experience high reductions in the industry sector, did lower their final energy consumption significantly due to structural changes. As solution to this problem in the work-in-progress ‘hard-link’ will include both options: the connection to a well equipped macroeconomic model, as well as such a second-best econometric and partial analytic solution in the case that input data from macro-economic models are not available. For the further disaggregation of industrial sector value added into subsector values for the manufacturing branches the importance of intra-sectoral structural changes was discussed, and again illustrated by using case studies for Germany, France, and Italy, as past structural changes has led to changes in final energy intensities of the manufacturing branches. To cope with the issue of intra-sectoral structural change in manufacturing industry, the planned ‘hard-link’ will use an econometric analysis and then typify these patterns of structural change for the different industrial branches. After its finalisation, the work-in-progress ‘hard-link’ including the transformation module will consist of different approaches including econometric, technological-econometric and partial analytical approaches as well as expert estimates. The transformation module will in addition to GDP and population also use data on per capita income of a country, foreign trade, material efficiency assumptions, recycling trends, quality improvements, etc. Long term projections of GVA at the sectoral level of basic industries are still not a sufficient information for energy demand projection, as many influences determine the final energy demand of such an industry: changes in the product structure with different energy intensities, changes of primary and secondary materials, particularly in the metal producing sectors, changes in the production processes (e.g. in the chemical industry). In addition, quality changes and additional product accompanying services may increase the GVA of a branch, but physical production may decrease and, hence, final energy demand. This is why the authors intensify their research on these issues of intra-industrial structural change and try to develop causal relationships of these influences for a hard link between the two types of models. The results of both models will improve quite substantially and model runs will be easily possible for simulating new energy policies or technical invocations.