DREAM

Danish Research institute for
Economic Analysis and Modelling

GREEN REFORM

Production technology in the CGE-model

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Introduction

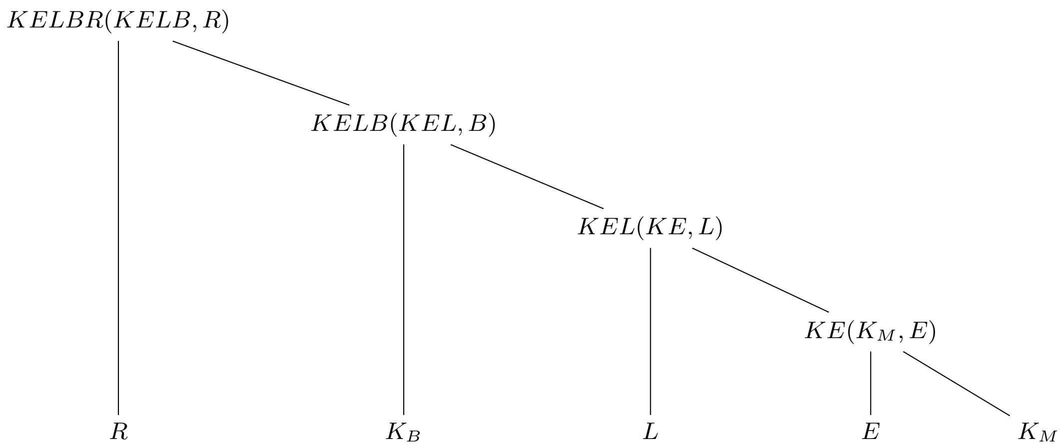
Firms in a given sector tries to maximize the discounted value of their dividends subject to the capital accumulation of real and book value capital and subject to the sector specific production function. We refer to this as the 'Firms problem'. Within that context, this note describes the production structure in the CGE-model of GreenREFORM at the present stage of development. Production technology will be different in those sectors covered by sector specific models.

Firstly, each sector use a combination of materials, energy and capital as inputs to produce a single artifical compound intermediate output. The technological transformation of inputs into intermediary output is described by nested CES production functions. Secondly, intermediate output is transformed by a CET function into a number of final outputs. In each sector final output consists of a single anstract sector specific good and (possibly) an array of non-abstract energy goods. Energy goods are non-abstract in the sense in that they are described in physical units of energy content. In some cases they are produced by more than one domestic sector, and most are also subject to supply by imports from abroad. At present there is 58 domestic sectors and 25 energy goods, and thus 83 types of final output in the model. In inputs, each sector specific good is complemented by an imported good differentiated by assumption of imperfect substitution (the Armington approach).

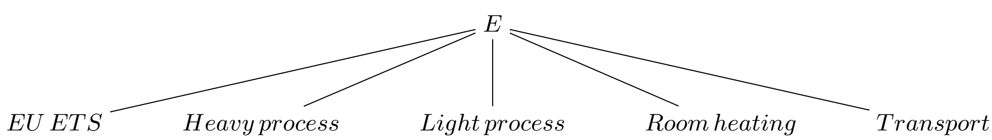
Data will determine the initital mix of inputs and outputs in each sector. Technology is bound to that particular mix, but firms will adjust proportionate levels of inputs and outputs in response to changes in relative prices. The responsiveness of such technological adjustment to prices relies on the choice of nesting structure and of parameter values in the CES and CET functions of each nest. In a given nest constant elasticity of substitution (hence CES) applies between inputs. The nesting structure provides flexibility, in that it makes it possible to specify different degrees of substitution between select groups of inputs.

Production inputs: Materials, energy, and capital

Every sector, s, has a nested CES production function with input of materials, $R_{sp,t}$, capital (excluding inventories), $K_{k,sp,t-1}$, energy $E_{sp,t}$ and labor, $L_{sp,t}$. Capital excluding inventories, $K_{k,sp,t-1}$, consists of building capital, $K_{iM,sp,t-1}$, and machinery capital, $K_{iB,sp,t-1}$. The nesting structure is of the typical KELM type, as illustrated below, but with M for materials replaced with R and with building capital. $KELBR_{sp,t}$ is intermidiate output as outlined in the introduction. Except for the seperation of energy from materials, the input nesting structure is identical to MAKRO, another CGE-model currently being developed by DREAM.



By further CES-nesting, materials (R) is an intermediate product of a mix of inputs of the sector specific goods, and with a further distinction between domestic supply and imports. Building and machinery capital (K_B and K_M) is accumulated via investments and subject to depreciation as part of the broader scope of 'the firms problem', cf. the introduction. The firm hires divisible productive units of labor (L) rather than persons. Labour is defined in effeciency units, which implies that working hours are weighted by a productivity factor (based on observed wage differences). Energy (E) is like materials an intermediate product. Firstly, energy is nested into 5 categories (see below) resembling differences in taxation. Secondly, within each category, energy is nested into a mix of energy types. Importantly, unlike materials, energy is not distinct by its source of supply. Imports and domestic products from all sectors are considered perfect substitutes, purchased at a uniform price. The modelling of supply and demand equilibrium of energy is described in a seperate note.

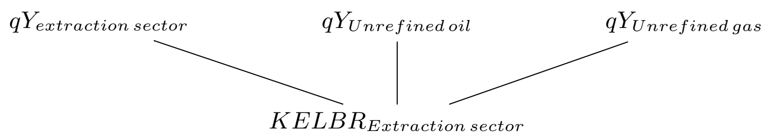


The category $EU\, ETS$ is processes covered by the European Emission Trading Schemes (CO_2-kvotesystemet). $Heavy\, process$ (Tung process) and $Light\, process$ (Let/alm. process) are non-ETS processes eligible to reduction or excemption from the standard tax rates on energy use. $Room\, heating$ is the remaining part covered by standard tax rates, except for electricity for room heating. In the data we have at present this is grouped together with electricity for appliances etc. in the category $Room\, heating$. Finally, the category $Transport$ covers all fuel (ie. not electricity) used for transportation, which is also covered by special regulation. Further development on the nesting structure and categorisation of energy usage is needed, both in order to match existing tax bases, but also to model important technological distinctions as best as possible.

Production outputs: Sector specific output and energy goods

As described above, the intermediate output $KELBR_{sp,t}$ is transformed into final outputs $qY_{out,sp,t}$ by a CET function, where subscript *out* is used to describe the single sector specific good and the whole range of energy goods. [skriv i fodnote om installationsomkostninger]

As described in the introduction, the possible mix of outputs is defined by data. For example, the oil and gas extraction sector produce the two energy goods unrefined oil and unrefined gas, as well as an abstract sector specific good. The later is there to match national account statistics, in which the value of production of the energy goods, even for a specialised sector like this, will not amount to the total value of production of the sector:



Technological change

GreenREFORM features Harrod-neutral labor technical progress. This implies, that the efficiency per working hour is steadily increasing across all sectors. Thus, for a given work force, the overall production capacity of the economy will grow by the same pace.

A total factor productivy scale parameter is applied to the compund intermediate output $KELBR_{sp,t}$. This parameter is at present only used for the purpose of adapting technology in two specific sectors, which both produce central district heating and electricity, such as to make the CGE-model conform with the more detailed describtion of technology (etc.) in the energy sector model. For the same purpose, and in some other cases, we will also allow for dynamic adjustment of input efficiency scale parameters of the CES-functions.

Our strategy for integrating the two models is described in detail in a seperate note.

As described in the introduction, firms will adjust technology in response to changes in input prices. In many energy and climate CGE-models, this standard feature is used to model firms technological abatement efforts, ie. technological change by wich to reduce input of fossil fuels and thus emissions (or just the emissions). In GreenREFORM, technological abatement will be modelled explicitely in a dedicated sub model. The interaction between this sub model and the CGE-model will likely leed us to introduce more adjustment features to the production function.

Future changes to production structure

We are currently working on modelling firms and households own production of transport services and of energy (heat and elecricity). Both will leed to changes in the production structure.

In the case of transport, firms and househoulds aquire transport services as inputs from a rather large number of transport sectors. These are divided into land, sea, and air transport, and further subdivided into cargo and people transport and into short and long haul transports. Transport services are at present part of the material input nest $R_{sp,t}$. But firms and households also produce transport services themselves as in integral part of production (or consumption). At present the input of transport fuels are modelled explicitly as decribed above. Firms transport vehicle fleet is part of machinery capital, while household vehicles are modelled as non durable goods. In the transport sector model, investments, maintance costs, accumulation and scraping will be modelled explictly. Obviously, the choice of transport fuels (including electricity) is tightly linked to the vehicle stock, and thus should be placed together in the nesting structure. It is undecided, as it is less obvious, if transport services and own production of transport services should also be placed together.

Likewise energy used for heating buildings should perhaps be nested together with building capital, and we also need to consider households and firms options to produce and store electricity themselves, rather than purchasing it off the grid. Small scale storage and and production of electricity will be modelled explictly in the energy sector model. However, in the CGE-model, where the circulation of incomes and transfers are modelled, we also need to address it, because of differences in tax rates and subsidies etc.

As decribed in the introduction, the nesting structure is important for the behaviour of firms in response to changes in relative prices between inputs. A more elaborate structure provides more flexibility, but at a cost of transparancy, and at a cost of increasing the complexity and computaional size of the model. It is also important to realize, that if the elasticity parameters are identical in an upper and the next lower nest, the nesting strucure makes no difference. It can be shown mathematically to collaps. Therefore, the structure should not be more elaborate than it needs to be. At present we have chosen a fairly standard production structure. It is similar to our own model MAKRO, and to many other CGE-models as well. This makes it possible to take parameter values from other models, and to compare the choise of parameters across models. We plan however, to do our own estimations on parameter values, by applying innovative estimation techniques and tools developed by DREAM for MAKRO. This work may also cause us to revise the choice of production structure.