Task 2: Linking core and extended models

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Coupled Model List

(with specific attention to policy issues the model can address)

Model	Sustainable Transport	Sustainable Consumption and Production	Management of Natural Resources	Public Health	Social Inclusion, demography and migration	Global Poverty and Sustainability Challenge
DART	no	yes	yes	no	no	yes
DEMETER	no	yes	no	no	no	no
EU-FASOM	no	yes	yes	no	no	no
GAIN	yes	yes	no	no	no	no
KLUM	no	yes	yes	no	no	no
ICES	no	yes	yes	no	no	yes
IMACLIM-S	no	yes	no	no	work in progress	no
IMACLIM-R	yes*	yes	no	no	no	yes
IMPEC	no	yes	no	no	yes**	no
MARKAL	no	yes	yes	no	no	no
PACE	yes#	yes	no	no	*planned*	no
WITCH	no	yes	yes	no	no	yes
W8D	no	yes	no	yes##	yes	no

* as an ex post extension.

** social security system, distribution of income by age

excluded in the TranSust.Scan version

state of public Heath approximated by life expectancy, a few exogenous variables explaining life expectancy (investment on health services, life styles, etc.)

Brief Model Description

DART

DART is a multi-regional, multi-sectoral recursive dynamic model of the global economy. It is especially designed to analyze international and European climate policies and includes the most important greenhouse gas CO2 resulting from the burning of fossil fuels. The time horizon of DART is until the year 2050. Concerning European climate policy DART is in particular able to simulate the European emissions trading scheme. The National Allocation Plans for the 1st and soon also for the 2nd trading period are implemented in order to compare actual to optimal EU climate policies. The model is also able to capture different assumptions about the use of the flexible Kyoto mechanisms CDM and JI and the supplementarity requirement of the EU. A special focus is always on the allocation and welfare effects of different policy regimes and proposals. Competitiveness effects for different sectors can also be analyzed with DART.

Concerning any sustainability analysis DART focuses on the issue of climate change only. In this respect an outcome of any policy scenario - e.g. also for a policy scenario that implies that a certain GHG level is achieved -are the resulting consumption and production patterns that are in line with this target. Even though DART has not been used for poverty analysis yet, it can in principle be used for such an analysis since distributional effects are covered as well. It would be necessary though to make some extensions (e.g. skilled vs. non-skilled workers). Concerning the management of natural resources, we are currently starting a project to couple DART with a GIS based land-use model of Germany and Europe to assess the role of land use changes and bio-energy for efficient climate policy. Due to its high aggregation level and global focus issues such as sustainable transport, public health and social inclusion, demography and migration can not be analyzed with DART.

DEMETER

DEMETER uses a top-down approach to address the sustainability challenge, and in particular allows for analysing the transition from the use of carbon-fuels to non-carbon energy under strict climate change mitigation targets. In addition to three stylistic energy resources, fossil-based energy, renewables, and fossil-based energy complemented with CCS technology, all three at the production side of the global economy, DEMETER allows for an endogenous simulation of energy demand and thus allows for the modelling of energy consumption behaviour as well. In its current form, DEMETER does not include a simulation of transport or the availability of natural resources.

EU-FASOM

EU-FASOM is a partial equilibrium model of the European Agricultural and Forestry sectors. It has been developed to asses the impacts of changing policies, technology, resource use, and market structures. It is possible to link EU-FASOM to other models. The model is based on management choices both in agriculture and forestry. Recognizing constraints stemming from limits on resources and other inputs, commodity outputs or increases in resource stocks can be determined. It is the objective of the model to maximize the surplus accrued from agricultural and forest activities while satisfying all constraints.

Applications of EU-FASOM include assessments of environmental impacts arising from agricultural or forestry activities and possibilities of their mitigation. Emissions of greenhouse gases and their reduction are accounted for in the model if they relate to agriculture, forestry, or ecology. Current work is in progress to extend the model to include the production of biofuels and their consequences for emissions of greenhouse gases.

GAIN

The energy module of GAIN follows the technology wedges approach proposed in the widely acclaimed paper Pacala and Socolov (2004). This modeling paradigm emphasizes the causality from energy services via end use energy flows to primary energy by specifying the relevant application and transformation technologies. This methodology identifies technology options and simulates the impact of these options given the implementation of a particular technology with a specified intensity.

For this structural modeling approach we partition the energy system into transport, industry, and the remaining sectors and link for a baseline scenario economic activity to the final energy demands of the sectors which in turn determine the primary energy flows. We interpret the path of baseline final energy as an indicator of energy services.

For policy simulations we are able to deal with the following policy measures:

- Reduction of redundant energy services (as idle services for heating and lighting)
- Substituting final energy flows by enhanced application technologies (as improving in the thermal structure of buildings).
- Raising the transformation efficiency (e.g. by switching to cogeneration and polygeneration technologies)

- Fuel switching (e.g. by substituting fossil energy by renewables)

For each measure we investigate the impact on investment and the impact on operations which in turn are checked for their impacts on macroeconomic indicators and emissions. Improving the thermal structure of buildings, e.g., creates demand for investments in construction and lowers the demand for energy flows which are contained in private consumption expenditures.

This modeling approach which has been implemented for 17 EU member states will be extended to the remaining EU countries. The simulations done so far deal with the 2020 targets as decided by the European Council in March 2007 on energy efficiency, greenhouse gas emissions and the share of renewables.

ICES

The ICES model is a standard recursive dynamic computable general equilibrium model of the global economic system. Its time horizon is 2000 – 2050. As a natural feature of CGE models it can analyse international and intersectoral economic impacts of different taxation and trade policies. In particular economic implications of climate change mitigation policies can be assessed as major GHG gases are represented. Emission trading for CO2 is already embedded; N2O and CH4 emissions are modelled, but an emission trading scheme for these gases needs to be built (which is one of the direction of the present research). The inclusion of sulphur emissions is another next step. The issue of sustainability can be addressed as well, this either considering directly the impacts of climate change and of climate change policies on consumption and production levels, or extracting from the model a set of sustainability indicators of environmental, economic, and social nature (e.g. employment, income, use of natural resources, emissions etc.) whose changes respect to a reference case can be measured. Distributional issues can be considered: the model already allows for high and low income workers, this can be further expanded including different income classes (though this is not one of our near term research interest). Finally, at an aggregate (national) level, costs and benefits of "generic" health policies can be simulated. This requires some modification of the model though, for instance changing the composition of government expenditure in favour of health care services and at the same time simulating the expected impact on labour productivity.

IMACLIM

IMACLIM (Impact Assessment of CLIMate policies) models have been developed at CIRED since the beginning of the 1990s, with the purpose of providing multiregional and multisectoral top-down equilibrium frameworks open to hybridisation with energy systems analysis.[2]

A static version of IMACLIM, IMACLIM-S, resorts to comparative statics to provide insights at some long-term horizon, where the transition from a reference growth path to a carbon-constrained equilibrated growth path is completed—under the assumption that the constraint is anticipated enough to avoid transitory disequilibria that would affect long-term equilibrium relationships. It focuses on the sensitivity of macroeconomic impacts to the particulars of the policy tool triggering abatement: tax reforms, trading systems with varying auctioning and recycling assumptions, technical or emission standards, etc. The paramount choices of producers and a representative consumer are represented through envelop functions reproducing the varying point-elasticities revealed by a coupled energy-systems analysis (the POLES model, from IEPE Grenoble, for the current version of the model). An endogenous technical change function linking general factor productivity to aggregated investment completes the description of technology evolutions.

Developments of IMACLIM-S planned in a short-term include the disaggregation of the current representative household of each region in 6 household classes, defined under the double criterion of income and activity. This will allow the model to start researching issues of social coherence and demography.

The recursive model IMACLIM-R is a dynamic structure articulating, on a yearly basis along an endogenous growth path, a succession of static general equilibrium frameworks and of partial sector-specific modules covering (for the current version) energy production, transportation and industry. It focuses on the investigation of climate, energy and development inter-related issues, to better understand the role of (i) technical parameters of the supply and end-use equipments, (ii) structural changes in the final demand for goods and services (dematerialisation of growth patterns), (iii) micro and macroeconomic behavioural parameters in opened economies, in the shaping of long-term energy-economy-environment scenarios. Describing imperfect labour and capital markets, it is particularly relevant to analyse the sustainable growth issues facing the developing world.

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[2] Hybridisation appears a necessity to the macroeconomic modelling of climate affairs: the traditional production and utility functions, however precisely calibrated, are inherently ill-adapted to picture facts as 'stubborn' as the current and projected technologies of the energy systems.

In the framework of TranSust.Scan, IMACLIM-R projections of European road transportation activities were disaggregated to provide detailed results concerning the emission of local pollutants. Future steps in this area will consist in refining the assessment of carbon emissions from road transportation, in consistency with the transportation activities detailed rather than computed from approximate average coefficients applied to the aggregated activities.

IMPEC

The model IMPEC is a multisectoral macro model. This means that both industrial and macroeconomic variables are considered within the model. The model builds macroeconomic variables using industrial details (a "bottom up" approach). It is based on an input-output core but it also makes use of behavioral equations. The author of the approach is Clopper Almon who developed such a model for the US economy in the early 1960's, and continues his effort within the project INFORUM (Almon 1991).

IMPEC uses much of INFORUM philosophy.

The current version of the model consists of 54 types of products. The disaggregation is in agreement with the NACE classification be found in the Polish input-output table for 2000.

The final demand elements are either at the level of categories typical of a given group of final users' (households' consumption - 43 categories, exports by 13 groups of products, investment demand in 29 groups of sectors) or they are expressed globally (inventories, government expenditures). The relevant conversion matrices (or vectors) link the categories of final demand (households', government, investment and export demand) with the sectors of economic activity.

Value added is disggregated into several categories but this part of the model will not be used within the project as well as some econometric equations which are present in the full version of IMPEC. However the core of IMPEC model uses input-output relationships to generate:

- demand for products
- producers prices
- prices of final demand categories.

In the framework of the project IMPEC will be extended to cover several ecological and social aspects.

KLUM

KLUM is an agricultural land use model that serves as a dynamic link between the economy and vegetation in the context of integrated assessment modeling. With the land allocation algorithm in KLUM the optimal area shares of several crops are determined, recognizing the essential economic and biophysical aspects of land use decisions in agriculture. Due to its simplicity and flexibility the model enables online coupling, as well as long-term projections. The crop allocation process is based on profit maximization, assuming risk aversion and decreasing returns to scales. The aggregated allocation can be fed back to a CGE as production-specific land endowments, or to a DGVM to improve carbon cycle simulations.

KLUM is now extended to include irrigation by means of crop-specific irrigation demands and respective irrigation costs. KLUM-W allows analyses of the effects of changing water availability and irrigation costs on crop allocation. Possible assessments focus on irrigation decisions in the context of changing climatic, biophysical, and economic conditions that may lead to increasing water scarcity and competition for resources.

Simulations with KLUM-W coupled to other economic and/or vegetation models may help to provide insights in issues of future water use and crop production by e.g. exploring the feedbacks between irrigation volume and prices for energy and water, looking at the general impacts of climate change on the share of irrigated agriculture, or assessing the relationship between crop demand and sustainable use of water.

MARKAL

MARKAL is a model used to generate sustainable energy production scenarios, through a cost minimisation programme, that may involve both internal and external costs. By imposing climate constraints additional sustainability features are included, and consumption behaviour is accounted for by employing MARKAL's elastic demand version, for Europe in our case. While the simulation of H2 production has relevance for the transport sector, the power production is the main sector covered. Natural resources are included as well, as for many of the simulated energy technologies, e.g. the required fuel base and unavoidable energy resource constraints are accounted for.

PACE

PACE is a flexible system of computable general equilibrium (CGE) models which integrate the areas of economy, energy, and environment. The generic core of PACE is a standard multi-sector, multi-region CGE framework of global trade and energy use designated to assess major policy initiatives in a world that is increasingly integrated through trade. Departing from the generic core, the various PACE modules allow for the problem-specific analysis of policy interference at different regional and sectoral levels as well as time treatments (static, dynamic-recursive, intertemporal). The different PACE modules account for issue-driven priorities in the representation of details and functional relationships. There is a module that emphasize discrete technological choice in the energy system thereby featuring a bottom-up representation of alternative electricity supply options. Another modules incorporate a detailed description of labor market imperfections and public taxation to trace back the interaction of tax policies and involuntary unemployment (e.g. due to union-bargaining). Further modules include a disaggregate representation of different household types in order to allow for more detailed incidence analysis or a vintage approach to car stocks in order to investigate the implications of alternative emission regulation policies for automobile industries. More recently, an integrated assessment module has been added that links a reduced from representation of climate relationships with a comprehensive intertemporal multi-sector, multi-region model for the world economy.

WITCH

WITCH (World Induced Technical Change Hybrid model) is an integrated assessment model specifically developed for the analysis of climate change issues. The hybrid nature of the model, linking an optimal growth economy model with a climate module and a detailed description of the energy sector allow us to provide results on indicators belonging to these three areas.

The regional, game theoretical structure of the model allows us to perform cost benefit and cost effectiveness analyses assuming alternatively a cooperative or a non-cooperative behaviour of regions of the world. In doing so, we are able to compare a world in which a central planner optimizes the total world welfare to another world where each region optimizes its own welfare, taking as given all other regions choices (and externalities).

The WITCH model can be used to perform normative analysis of the policy scenarios that will be outlined. In particular, it will be possible to obtain information concerning the optimal investments in energy generating technologies and R&D, given the assumptions on emission caps. The game theoretic structure will in particular provide a tool to analyse the stability of the simulated agreements. The time frame of the analysis can be from the medium (2050) to the long run (2100). The climate module will also provide information on environmental effects of the analysed policy.

The model has been designed to perform normative analysis of the climate change issue, with a specific attention to feedbacks on the economic growth, on optimal R&D strategies and optimal energy technologies investments. Its specific focus on energy technology can be used to derive information on energy security issues. Its intertemporal nature is specifically tailored to deal with such a long term issue. The regional structure allows us to recognize the striking differences in technology and per capita incomes among world regions and the strong asymmetries of damages from climate change, mitigation costs and abatement potentials. These characteristics make the WITCH model well equipped to deal with this policy area.

It should however be noticed that the model is not a full bottom-up model, thus the level of specific technology information will be partly limited. Moreover, the sectoral disaggregation of the economy is very limited, thus sector-specific analyses typically performed by CGE models will not be possible.

W8D

The key tool of quantitative analyses related to the project – the W8D model of the Polish economy – had to be extensively modified, updated and extended to successfully deal with a variety of issues concerning sustainable development. This is so because its previous version was elaborated to cover mainly economic aspects of growth (see The structure of the long-term W8D-2002 macroeconometric model of the Polish economy). To this end, the general idea of a new version the model has been conceptualized and appropriate methodologies described (see paper Modeling various aspects of sustainability. The case of Poland).

In a nutshell, the main mechanisms underlying the structure of the new system might be depicted as follows. The core of the entire system rests on the initial version of the W8D model of the Polish economy, which to much extent affects the way the sustainability issues were treated. The central relation of the whole construction is a generalized production function comprising – apart from traditional production factors: built capital and labour force – human capital and endogenous technological progress. The human capital includes both education, learning by doing and health state of the labour force. To meet the requirements of such defined human capital measure one has to possess quite detailed information about the population by age structure. In the long-run it is also necessary to account for fertility. Life expectancy that stands for health indicator of the whole society influences labour productivity and is itself determined – among others - by economic, social and environmental factors. The standing of natural environment represented by air and water quality as well as by waste accumulation affects – among other things – life expectancy, and thus – indirectly – also labour productivity. Technological progress - associated in the model with total factor productivity - is a function of human capital, imported R&D, and science sector activity measured by a stock of accumulated patents. The individual blocks are in mutual, contemporaneous interlinks against one another, which is depicted in figure 1.

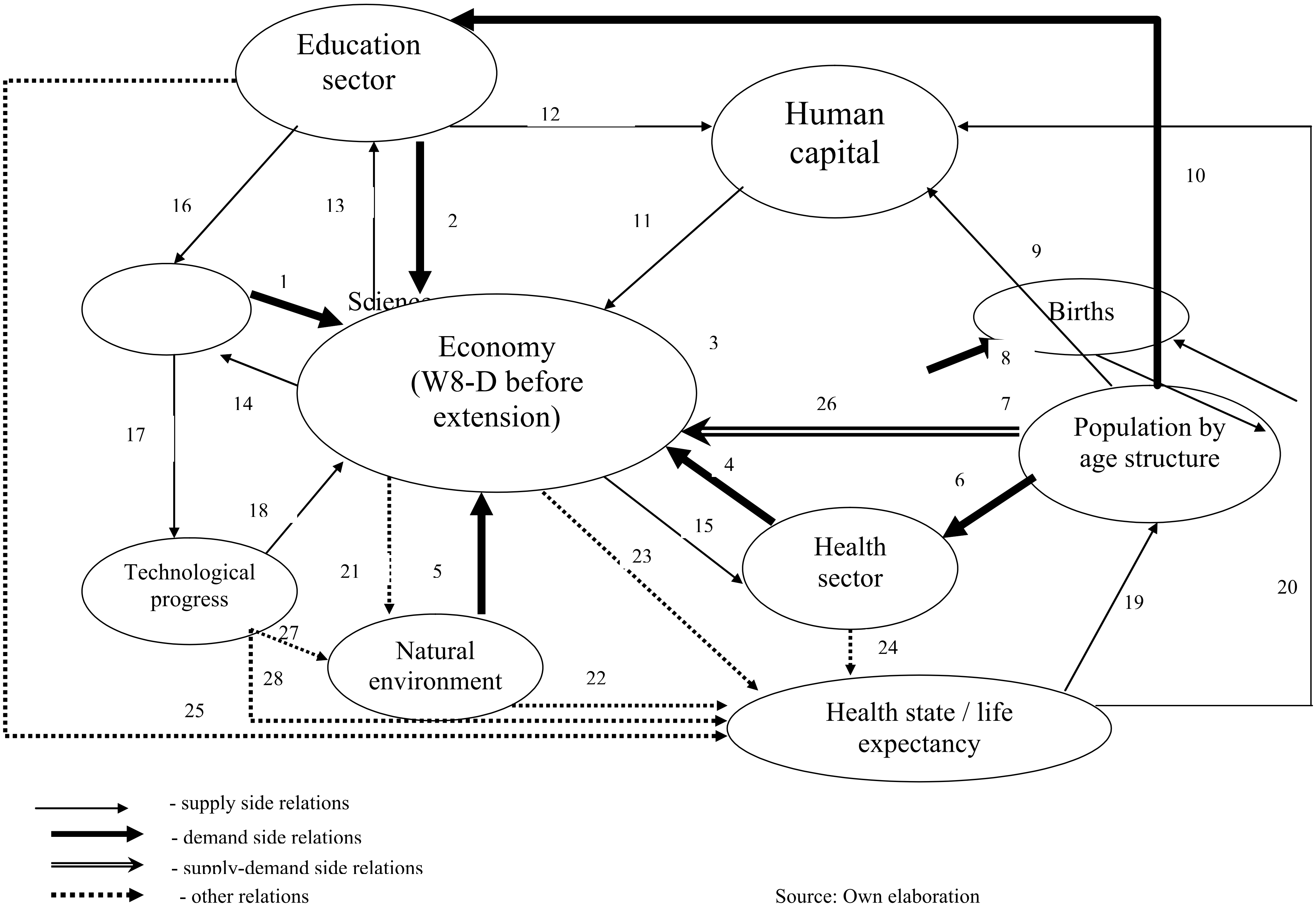
The outlined system of simultaneous relationships touches upon what constitutes the essence of broadly understood sustainability - not limited to ecological questions only – from a macroeconomic perspective with some priority given to economic growth. For obvious reasons is not, and cannot be exhaustive. This is both because of the taken (macroeconomic and national) perspective and - more importantly – because of inappropriateness of traditional econometric approach to deal with such vital aspects of sustainability as valuation of biodiversity or intertemporal fairness. Still, it is worth emphasizing that even in this form, the model might prove useful in analyzing various socio-economic policy decisions.

To broaden the range and of its possible applications and degree of comprehension, the W8D model will be connected to another model of the Polish economy IMPEC, based on input-output methodology. This will enable – amongst others - disaggregation of technological progress formation, economic activities and greenhouse gasses emission by sectoral or even branch breakdown. The W8D will be responsible for generating long-term, macro projections, whereas IMPEC – basing on the data generated by W8D – will disaggregate them – where possible - into sectoral or branch items.

Further comments

The work on construction of the new versions of the models is pending. An extensive data base consisting of both annual national (for 1960-2005 period) and regional panel data have been elaborated. Hypothesis concerning specifications of individual equations are being verified. All equations in the model must be re-estimated to take advantage of the latest information. All these are time and effort-consuming activities, which will take another 2-3 months before arriving at the simulation version of the model. Presentation of all individual equations is expected to take place at the workshop in Dublin in May, 2007. Then, depending on explicitly specified common assumption concerning BAU and alternative policy scenarios, the joint system will be employed to answer the questions risen in the project.

Figure 1. Macro-feedbacks between main blocks of the extended W8-D model



Source: Own elaboration