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Linking IMAGE 2 and WORLD SCAN

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Abstract

This paper presents the links between the climate model IMAGE 2 and the economic model WORLD SCAN, which are set up to obtain an integrated scenario instrument for comprehensive and consistent climate-economy scenarios. The links are made with respect to energy (in WORLD SCAN) and agriculture (in IMAGE 2), thus providing a consistent linkage with feedbacks running both ways.

1 INTRODUCTION

In March 1994, the CPB and the RIVM started the joint NRP-1 project 853139 "Linkage of WORLD SCAN and IMAGE-2 models". Purpose of the project was to devise an analytical tool for integrated comprehensive scenarios of world economic development, greenhouse gas emissions and climate change. It is a precondition for the follow-up project - which is in the running for NRP-2 funding - in which "greenhouse policies" are analyzed on the basis of two reference scenarios for world economic development, bringing to the fore an assessment of fundamental uncertainties regarding crucial economic developments. The two reference scenarios to be developed differ according to the rate of convergence of the world's regions, in terms of economic, political and social developments. Questions with respect to the lifestyles, the openness of economies, and technological catching up by less developed regions will be addressed in this framework. Greenhouse policies to be analyzed include regional and interregional tax measures and regulations to curb emissions of CO_2.

This paper first provides an overview of both models in section 2, after which section 3 digresses on the adjustments in both models. Section 4 pulls together the threads and hints on the type of analysis to be made in the NRP-2 project, after which it concludes the paper.

2. THE TWO MODELS

As models always paint a simplified picture of the real world, WORLD SCAN and IMAGE both provide a consistent treatment of a sub-system. The former is an elaborate world economic model remaining relatively blind for environmental feedbacks. The latter describes climate change processes in a consistent manner, while treating economics as an exogenous input.

2.1 WORLD SCAN[1]

The CPB WORLD SCAN is a theory-based, multi-sector multi-region long-term world economic model, in which three basic paradigms of economic development are present. These paradigms coincide roughly with the Neo-Classical, the Keynesian and the Schumpeterian views. As most models in the climate discussions are Neo-Classical of nature, *e.g.* GREEN[2], we will focus here on how WORLD SCAN deviates from the Neo-Classical perspective. The central extension of the model in a Keynesian direction is the role of investment behaviour. The explicit investment decision is based on expectations about the future and is driven by unstable "animal spirits". Schumpeterian tensions on markets are modelled by letting stocks determine market outcomes and non-wage incomes. Moreover, returns on investment are uncertain due to the uncertainty with respect to future economic and technological developments. A characteristic feature of the model is that it exhibits short-term disturbances, which have their impact on long-term developments. It is the analysis of these crucial issues which is left out in more Neo-Classical economic analyses of greenhouse policies.

2.2 IMAGE 2.0[3]

The RIVM IMAGE 2 model is a multi-disciplinary integrated model designed to simulate the dynamics of the global society-biosphere-climate system. The objectives of the model are to investigate linkages and feedbacks in the system, and to evaluate consequences of climate policies. Dynamic calculations are performed to the year 2100, with a spatial scale ranging from grid (0.5° x 0.5° latitude-longitude) to world regional level, depending on the sub-model. The model consists of three fully linked sub-systems: Energy-Industry, Terrestrial Environment, and Atmosphere-Ocean. The fully linked model has been tested against data from 1970 to 1990, and after calibration can reproduce the following observed trends: regional energy consumption and energy-related emissions, terrestrial flux of CO_2 and emissions of other greenhouse gases, concentrations of greenhouse gases in the atmosphere, and transformation of land cover. The model can also simulate long term zonal average surface and vertical temperatures.

3. THE LINKS

The two overlapping areas of the models are agriculture and energy. The first is affected directly by climate change and has feedbacks to economics, while for the second the major feedbacks run from economics to climate. The links are therefore embedded in the agriculture module of IMAGE and a new energy system in WORLD SCAN.

3.1 Integrating Energy in WORLD SCAN

In WORLD SCAN we have taken the same end-use approach as in IMAGE 2, by translating all demand for the energy services heat and electricity into demand for primary energy carriers. In contrast to IMAGE, throughout nested constant-elasticity-of-substitution (CES) functions are used, which allow cost-driven substitution between and within bundles of items. This runs via two channels: intermediate demand for energy services stemming from production and final demand stemming from consumption.

Intermediate demand for energy is illustrated in the input-output matrix presented in table 1 below, where shaded areas indicate deliveries. We have created two intermediate sectors - electricity and other intermediates - which use raw materials and primary energy and deliver the energy services to the other sectors. As can be seen immediately, this results in a simple matrix with no intra-sectoral deliveries. The intermediate demand for primary energy is split into oil, natural gas, coal, and biomass.

Table 1 The Input-output Matrix of WORLD SCAN

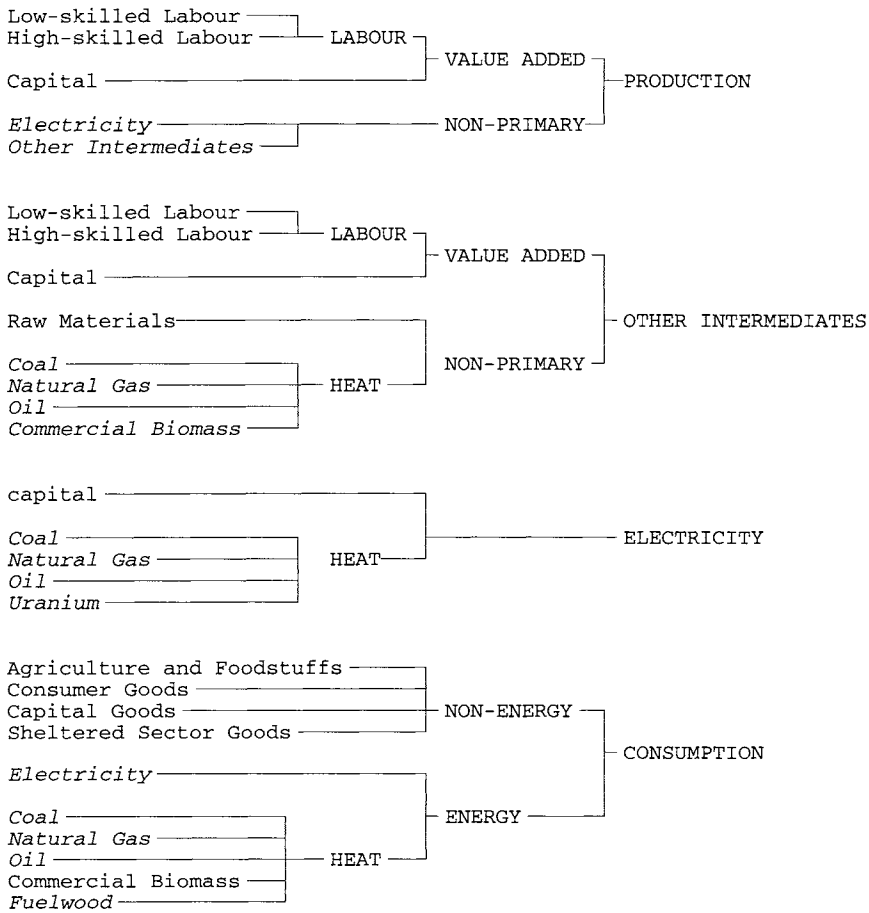
	primary energy	raw materials	electricity	other intermediates	other sectors
primary energy					
raw materials					
electricity					
other intermediates					
other sectors					

Next to intermediate demand, there is final demand for energy, which is divided into consumption and net exports, where net exports are the result of both consumption and intermediate demand for energy in other regions. Consumption demand is divided into energy and non-energy, with energy divided among heat and electricity. Heat for consumption consists of the fossil fuels, fuelwood (in LDC's) and commercial biomass.

In figure 1 below, the nested structure of demand is presented. The trees illustrate the structure of demand for consumption and production. Every aggregate branches off according to a CES function. Left-side items in italics refer to links in the energy chain.

All demand is fed back fully into markets for energy, products, labour and financial capital, and the resulting energy use is delivered to IMAGE 2 as input in the Energy-Industry model. Markets for energy are - for now - modelled with perfect competition regimes, with stocks playing a role for fossil fuels. Primary energy supply is modelled as production sectors with decreasing returns to scale and exogenous technological progress, reflecting the finite character of the resource base[4].

Figure 1 An outline of demand structures in WORLD SCAN



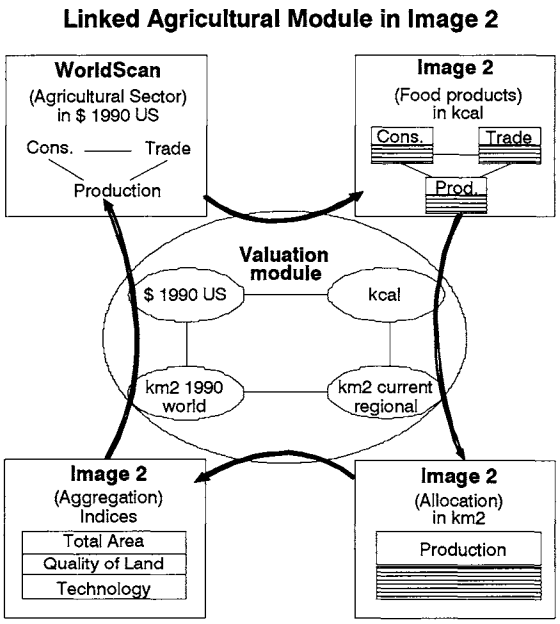
3.2 Agriculture in IMAGE

Transformations of global land cover are strongly related to changing land use for agricultural products, which require croplands, pasture land, rangelands, and managed forests. The purpose of the Agricultural Economic Demand (AED) Model is to estimate demand for agricultural products. It is developed to be included in the IMAGE 2.1 model within the Terrestrial Environment sub-system. The main driving forces are population growth and income (Gross Domestic Product).

The AED Model covers physical as well as economic aspects of agricultural production and consumption. The conversion of economic data into physical data and vice versa is done in the valuation sub-module. WORLD SCAN computes regional consumption, production and trade of aggregated agricultural products. First, economic

flows (in constant prices) are converted in the AED Model to physical flows, expressed as the demand for land (km2). Secondly, shares for twelve different food products (seven crops and five animal products) are computed. These are derived from utility maximization, given total available land for production. For the next period, allocated land in combination with quality indices for production are used to alter technical coefficients in the production functions of WORLD SCAN.

Figure 2 The linked agricultural module in IMAGE 2



4. CONCLUDING REMARKS

With the instrument developed in NRP-1 we will develop two reference scenarios in the NRP-2 project. Economic, political and social characteristics of the reference scenarios have their effect for instance on the composition of food bundles determined in IMAGE and on the consumption structure in WORLD SCAN. Furthermore, economic development differs widely between the two scenarios letting growth, trade and sectoral structures be very different. This affects the energy inputs for IMAGE in a strong way, leading to characteristic scenario profiles. Subsequently, extensive policy analyses can be performed in the two reference scenario worlds.

Concludingly, we may state that the project has resulted in a remarkable and powerful tool for integrated economy-climate scenario analysis. Especially the combination of the original economic features of WORLD SCAN with the accepted and well-founded climate analyses of IMAGE contributes to the distinct qualities of the intrument. When NRP-2 funding for the scenario project comes through, we are convinced that new economy-climate scenarios can be developed which can shape policy discussions on the interaction between climate change and economic development.

1 WORLD SCAN was developed as analytical tool for the scenario study "Scanning the Future" published by Sdu Publishers, Plantijnstraat, The Hague in 1992. We refer to CPB internal notes IV/94/30 - IV/94/32 for a detailed description of WORLD SCAN.

2 GREEN is the GeneRal Equilibrium ENvironmental model of the OECD, which has played a major role in the first discussions on greenhouse policies. See for instance Working Papers No's 116 and 143 of the OECD Economics Department for a description of the model and its performance in the inter-comparison projects of the OECD and the Stanford University Energy Modelling Forum.

3 We refer to J. Alcamo (Editor) "IMAGE 2.0 - Integrated Modeling of Global Climate Change", Kluwer Academic Publishers, Dordrecht, 1994.

4 Technological progress is negative in these sectors, acting as a proxy for depletion. A resource depletion model is not included but will be, if relevant.