Global Multisector/Multicountry 3 - E Modelling: From COMPASS to GINFORS

Bernd Meyer[ab]*, Christian Lutz[a], Marc Ingo Wolter[a]

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Abstract

The global dimension of environmental policy, which has become a subject of international policy with the concrete discussion of targets and instruments, constitutes a huge information gap for environmental policy. The authors postulate, that this can only be filled by the application of global economic environmental models, which have to meet certain requirements: A multisector and multicountry system with global coverage and bilateral trade linkage with econometrically estimated parameters is needed. The authors present the system COMPASS (**Co**mprehensive **M**odel of **P**olicy **Ass**essment) and the improved system GINFORS (**G**lobal **In**terindustry **For**ecasting **S**ystem), which is just being constructed based on the experiences made with COMPASS. A discussion of the application of GINFORS in the EU project MOSUS (**M**odelling **O**pportunities and Limits for Restructuring Europe towards **Sus**tainability) gives an impression of the power of the model to analyze global economic environmental questions and to forecast important environmental indicators.

Keywords: economy-energy-environment models; environmental policy, global modelling

*Corresponding author: Tel.: +49-541-40933-14; fax: 0049-541-40933-11. E-mail: meyer@gws-os.de.
[a] *Gesellschaft für Wirtschaftliche Strukturforschung (GWS) mbH, Weissenburger Strasse 4, 49076 Osnabrück, Germany;* [b] *University of Osnabrück, Rolandstrasse 8, 49076 Osnabrück, Germany*

1 Introduction

The global dimension of environmental problems stresses the need of an internationally linked environmental policy. The example of climate change policy shows, that environmental policy has to be a subject of a globally oriented international policy formulating operational targets, that allow for global sustainable development in the environmental, economic and social dimension. Further, a set of policy instruments has to be installed, that will enable to reach global sustainability.

Already from a political point of view the task seems to be huge, and there are many sceptical voices, whether the big political bargaining process could ever converge. A necessary but by no means sufficient condition for this is the solution of a big information problem: What does sustainable development mean for the different countries, when it comes to the formulation of *operational* targets for the use of the environment, the economic and social development for the future? How are the *relations* between the targets? What do we know about the interdependencies between the environment, the economic and the social development in the different countries? How do the different instruments affect nature and the paths of economic and social development? How is the efficiency of these instruments?

Only simulations and forecasts with models, which depict the interdependencies between the environment and economic and social development, can give us answers to these questions. Of course, such models have to fulfil certain requirements. In section 2 we will discuss this point from the perspective of a concrete policy project. The MOSUS project "**M**odeling **O**pportunities and Limits for Restructuring Europe towards

SUStainability", which is funded by the 5th framework program of the European Union, tries to give answers for the above quoted questions. We will show, why the model COMPASS (**CO**mprehensive **M**odel of **P**olicy **ASS**essment) (Meyer/Uno 1999, Uno 2002) was chosen as simulation tool in the project.

In section 3 COMPASS is shortly presented and necessities are discussed, which demand for a further development of the system. We will see, that the construction of a new model named "GINFORS" (**G**lobal **IN**terindustry **FOR**ecasting **S**ystem) based on the experiences made with COMPASS is the better alternative. In section 4 we will discuss the structure of GINFORS. Our conclusions in section 5 will show the ability of the system to give answers to the questions formulated at the top of our paper.

2 The MOSUS Project and its Challenge for Modelling

Since the Gothenburg summit in June 2001 the concept of Sustainable Development is in concrete terms a dominant guideline for the policy of the European Union (EU 2002). The commission presented an overall strategy, which demands to examine the links between economic, social and environmental policies to make them more compatible with Sustainable Development. Since the European socio-economic development and its use of the environment has impacts far beyond the borders of the community, the Sustainable Development Strategy explicitly stresses, that the development of the European Union has to be analysed within a global context.

The MOSUS project (www.mosus.net) is the ambitious attempt to identify possible strategies for a sustainable development in Europe considering the interrelations of

- resource inputs, land use, energy consumption,
- economic development, and
- fundamental social indicators.

As part of the 5th framework programme of the European Union MOSUS started with the kick-off meeting in March 2003. MOSUS is endorsed by the Industrial Transformation Project of the International Human Dimensions Programme (IHDP-IT). Partners of the project are 12 research institutes from 8 European countries.

There are five requirements, which the simulation model used in the MOSUS project has to fulfil:

1. It has to be a *multicountry* global model. The global coverage is already demanded in the strategy of the Commission. The multicountry approach is needed as policy decisions are made in countries and for countries and not in regions. Of course, all EU 15 and the accession countries as well as all other countries in the world, that are important from an economic and environmental point of view, have to be described explicitly.
2. A *multisector* model is needed: The interrelations between the economy and the environment with its complex structures for the different resources and emissions can only be depicted in a deep sector disaggregation of the economy.
3. From 1 and 2 follows, that *international trade* has to be analysed in a *multisector/multicountry* approach. This means, that for every product group, that is important to describe the economic-environmental interdependencies, the international trade between all important countries has to be depicted bilaterally.

4. The model has to give an *endogenous explanation of socio-economic development and its linkage with the environment.* This follows from the integrative approach of sustainability, that defines the MOSUS project.
5. The model must be able to describe concrete and realistic policy alternatives. How will the future be in the business-as-usual case? How can this path be influenced by instruments, that are in discussion. A *forecast* model is needed, which is able to reproduce the historical development because of the *statistical significance of its parameters*.

In the phase of the preparation of the proposal the research group checked the availability of global economic-environmental models and their usefulness in the context of the project. The most restrictive criterion is global coverage of the systems. Uno (2002) found and summarized not less than 34 global simulation models in the literature - most of them focussing on energy questions - that have been developed since 1993.

In 27 of these models economic development is *exogenous.* Since we are interested in the interdependencies of socio-economic and environmental development from an integrative perspective of sustainability, this is not acceptable. To this group Uno (2002) counts the models (in alphabetical order) Adam Rose - Brand Steven (Rose and Steven 1998), AIM (National Institute for Environmental Studies, Japan no date), APEC Energy Outlook (APERC 1996), ASF (IPCC 2000), DECOMPOSITION (Unander and Schipper 1998), DEMETER (van der Zwaan et al. 2002). ECN Study (Sijm et al. 2000), GemWTrap (Bernard and Vielle 1999), IEA Energy Model (Vouyoukas 1993), Ifs International Futures (Hughes 1999), IIASA and WEC (Nakicenovic et al. 1998), IMAGE 2.0 (Alcamo 1994), IPCC Special Report (IPCC 2000), MARIA (IPCC 2000), MARKAL Models (Loulou and Kanudia 2000), MARKAL MATTER (Gielen and Kram 2000), MERGE (Manne, Mandelsohn and Richels 1995), MESSAGE (IPCC 2000), MIDAS

(Capros et al. 1996), MiniCAM (IPCC 2000), MS-MRT (Bernstein et al. 1999), New Earth (Nishio, Fuji and Yamaji 2000), Rains-Asia (Resource Management Association 1996), RICE (Nordhaus and Yang 1996), WERS (Energy Information Administration USDE 1997), World Energy Outlook (International Energy Agency 1998), World Model (Duchin and Lange 1994).

Another five models endogenize the economy, but do not fulfil the requirements, since they are not disaggregated deeply: The EDGE Model (Jensen et al. 2000) distinguishes only 8 regions and 7 industrial branches, the models G-CUBED (Bagnoli, McKibbin and Wilcoxen 1996), GREEN (OECD 1994), PRIMES (European Commission 1995) and WorldScan (Bollen et al. 1999) distinguish only eight to twelve regions and eleven to twelve sectors.

The fundamental qualities - global coverage, endogenous economy and a deep sector and regional disaggregation - are accomplished by the models GTAP (Hertel 1997) and COMPASS (Uno 2002, Meyer and Uno 1999). GTAP distinguishes 57 sectors/commodities and 67 countries and regions, COMPASS distinguishes 36 sectors and 53 countries and regions. The core of both models is a multisector bilateral trade model, and both systems are modelling the interdependencies of economic and environmental (at least with respect to energy consumption) development. A broader modelling in respect to other environmental issues is possible, since the fundamental qualities of both models allow for it.

So at first sight, GTAP and COMPASS seem to be similar systems. But there is one big difference: GTAP is a CGE (Computable General Equilibrium) model, whereas COMPASS is a sectorally disaggregated macroeconomic model. West (1995) calls such models “econometric input-output models”. This means, that GTAP is based on neoclassical theory with the central assumption, that all agents are acting with full information in perfect competitive markets, so that all decisions are the result of optimisation based on some assumptions on the technology or the welfare function of the economy.

On the other side, COMPASS follows evolutionary theory assuming agents to decide under conditions of bounded rationality in non perfect markets. In this case it is not possible to derive decision rules from optimisation. Many more or less plausible decision rules for one specific activity compete with each other to be integrated in the model, and empirical evidence is needed to select the “right” one (Meyer 2003). So in general, sectorally disaggregated macroeconomic models consist of behavioural parameters estimated by econometric techniques, that exist for single equations. To evaluate multi-equation simulation models historical simulations have proved to be very important evaluation criteria (Pindyck and Rubinfeld 1998, p. 384ff.). The model is tested and equations are adapted until the development of endogenous variables tracks the historical data very closely. Thus, the model is validated empirically.

CGE models take their parameters from the literature and calibrate the rest by the data of one year. This means, that these models remain to be theoretical models, since every model structure can be adapted to one data point. On the contrary, parameter choice of econometric models is based on time series data. The set of parameters is tested, as the model must be able to reproduce history for a longer period and not only for one year.

In the case of GTAP the parameter choice takes place as follows (Huff, Hanslow, Hertel, Tsigas 1997): There are four types of behavioural parameters in the model: elasticities of substitution in production and consumption, transformation elasticities, which determine the degree of mobility for primary inputs between the sectors, the flexibilities of regional investment allocation and consumer demand elasticities. Let us focus on the specification of substitution elasticities of production and the elasticities of consumer demand, because they are most important for the behaviour of the model system.

There are three types of substitution elasticities on the different stages of the nested CES production functions, which depict the technology of an industry in a specific country: The substitution elasticities for the components of value-added, the elasticities for the substitution between domestically produced and imported intermediate inputs and the substitution elasticity between the imports from different countries, which are assumed to be identical for all countries (Armington hypothesis). These elasticities have been taken from a study of Jomini et al. (1991). All three types of substitution elasticities are different for the 57 sectors, but identical for the countries. This means, that it is assumed, that all countries produce with the same technology and do not distinguish or prefer imports according to the delivering countries.

The parameters of the constant difference elasticity (CDE) consumer demand functions are country specific, but the income elasticities for the different products have been taken from three sources: Food and Agriculture Organization (1993), Jomini et al. (1991) and Theil, Chung and Seale (1989). Based on these income elasticities own-price elasticities have been computed using further country specific information (Huff, Hanslow, Hertel, Tsigas 1997, p. 128ff.).

Models with this kind of parameter choice and a highly idealistic model structure will hardly be able to produce a realistic business-as-usual forecast for the different economies and their environmental situation (requirement 5). Therefore as a result of this study of the literature COMPASS has been chosen as a model system for MOSUS, which of course has to be adapted to the specific structure and demands of the MOSUS project.

3 The Model COMPASS and its Possible Adaptation to MOSUS

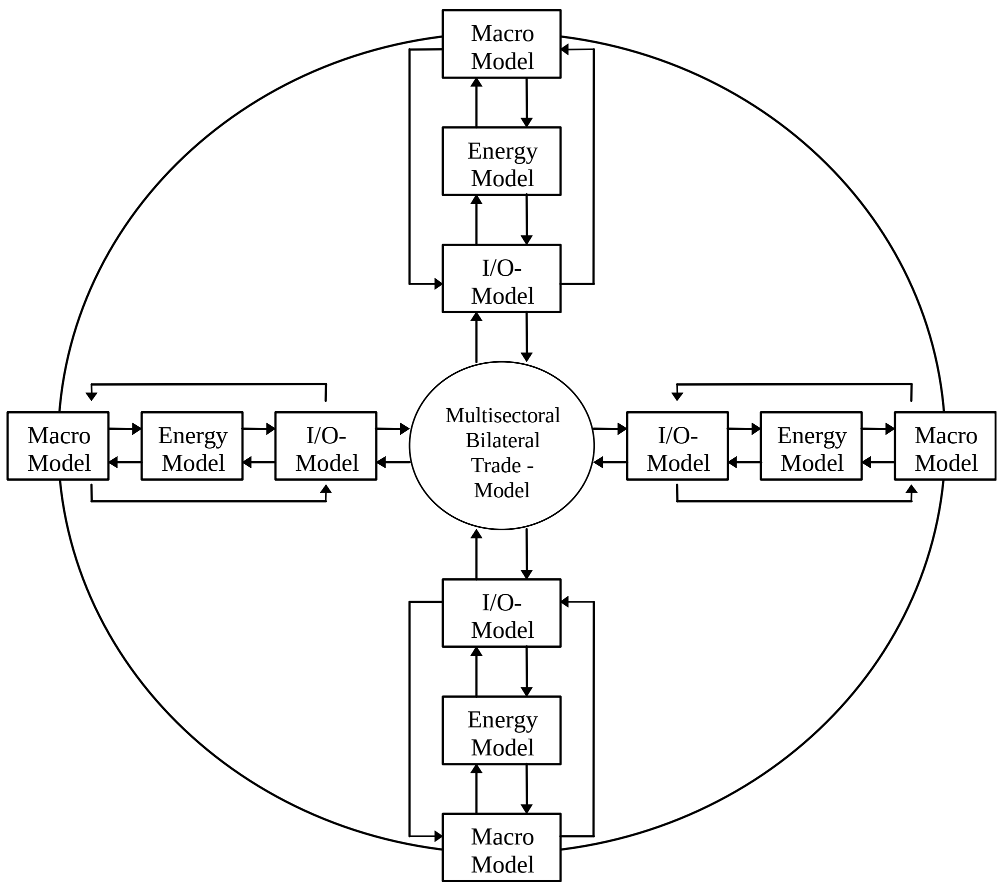
The structure of the global model COMPASS is depicted in figure 1, that shows a wheel, in which the bilateral trade model is the axis (Meyer and Lutz 2002a). The spokes are the country models , which always consists of a macro model and for many of the OECD and APEC countries of an input-output- model and an energy model. The tyre represents the linkage of the countries via the international financial markets.

The global trade model receives a vector of import volumes and export prices in US-Dollars (Meyer and Lutz 2002b). The trade model calculates the vector of import prices for every country. Further the trade model estimates the shares of country l in the imports of good i in country k depending on relative import prices for good i in the different countries. Then the vector of exports can be calculated for every country by definition.

The input-output models (Meyer and Lutz 2002a) consist of 36 sectors. They obtain the vector of export volumes and import prices from the trade model and get aggregated investment and private and public consumption from the macro models and disaggregate them for the 36 sectors. From the energy models the input-output models receive prices for the energy carriers. With the input coefficients as exogenous variables the input-output models calculate the vectors of gross production, intermediate demand and the vectors for the components of primary inputs as labour demand. The input-output models further estimate the vector of unit costs and the vector of prices.

The macro models (Meyer and Lutz 2002a) aggregate primary income, import volumes and prices coming from the input-output models. A fully endogenized System of National Accounts (SNA) calculates the income redistribution, the disposable income and net lending/net borrowing of the private households, the government and the firms. The macro models contain further monetary models with money supply, money demand, the discount rate and long term interest rates. The macro models estimate consumption and investment demand, that are - as already discussed - disaggregated in the input-output models.

Figure 1: The structure of COMPASS



The energy models (Umehara 2002) get from the input-output models production and consumption demand by sector, that are drivers for energy demand. Energy intensities for the different final energy demands are calculated and the computable energy demand is then disaggregated into demand for the different carriers. In the case of electricity and mineral oils the conversion of primary into secondary energy carriers is depicted. Structural change in energy demand depends on relative prices. The price of every carrier is also calculated in the energy models. Energy demand and its prices are then fed back to recalculate the energy rows of the input-output models.

The trade model contains 53 countries and regions. There are 31 macro models with a complete SNA system and a monetary model, for 22 countries the macro models are only so called “macro simulators” with calibrated final demand functions. The system contains 20 countries with input-output models and energy models.

Only international data has been used in the model: The trade model is based on UN data as well as the SNA models are. The monetary models are based on IMF data. The input-output data was taken from the OECD and APERC, the energy data from IEA.

There are two versions of the model existing, which are different in respect to the solution procedure and the solution time. The advanced version got the name GLODYM. The discussed structure of COMPASS/GLODYM allows for the use of the model as the simulation engine in the MOSUS project, but it was clear from the beginning, that several adaptations would be necessary:

- EU coverage inclusive accession countries,
- addition of material input models,
- addition of land use models,
- endogenization of consumption structures.

COMPASS/GLODYM covers all EU countries, but there are only 7 with input-output models and energy models. The EU accession countries are missing completely. For all 53 countries – as far as the data availability allows – models for the material extraction and for land use have to be constructed and to be linked with the system. Also depending from data availability – at least for the most important countries the structure of consumption has to be endogenized.

Further the up-dating of the whole system has to be done. The work on COMPASS/GLODYM started in 1996. Therefore the time series end at 1994 or 1996 and the input-output tables are from 1990. And of course the work of scenario formulation for the exogenous variables has to be done.

At the beginning of the project it seemed to be reasonable to build a new model system for MOSUS based on the experiences made instead of adapting COMPASS/GLODYM for three major reasons: First, statistical sector classification has changed world wide to SNA 93. This means, that an up-date of the old database would have been very difficult and time consuming, if possible at all. A second point is, that the OECD published in the last years a new dataset with multisector bilateral trade matrices, sectorally disaggregated data for primary inputs and SNA data with a disaggregation of consumption for most countries of the OECD and many of its trade partners. Last not least it should be mentioned, that the development of new modelling software allows for a new, easier to handle model structure.

The new model named GINFORS (**G**lobal **IN**terindustry **FOR**ecasting **S**ystem) is already under construction. It is based on the same philosophy as COMPASS/GLODYM, but it is based on a different data set and uses a different software. In comparison to COMPASS, the data will allow for more complex structures, and the interdependencies between the economy and the environment will be more modelled more completely. Especially on the side of the environment not only energy, but also material inputs and land use will be integrated. At the moment a first stage version with the trade model and all macro models is already running. The following chapter gives an overview of the whole system, that will be ready for work in about one year.

4 The Model GINFORS

Figure 2 shows the information about data sources and geographical coverage of GINFORS. The trade model uses OECD data, distinguishing 25 commodities and services as an additional group for 40 countries and the two regions OPEC and ROW (Rest of the world). The macro models are also based on SNA data from the OECD. Monetary variables are taken from the IFS statistics of the International Monetary Fund. There are macro models for 53 countries, which means, that 13 of these countries are not explicitly part of the bilateral trade model. Their trade is linked to the trade of the rest of the world.

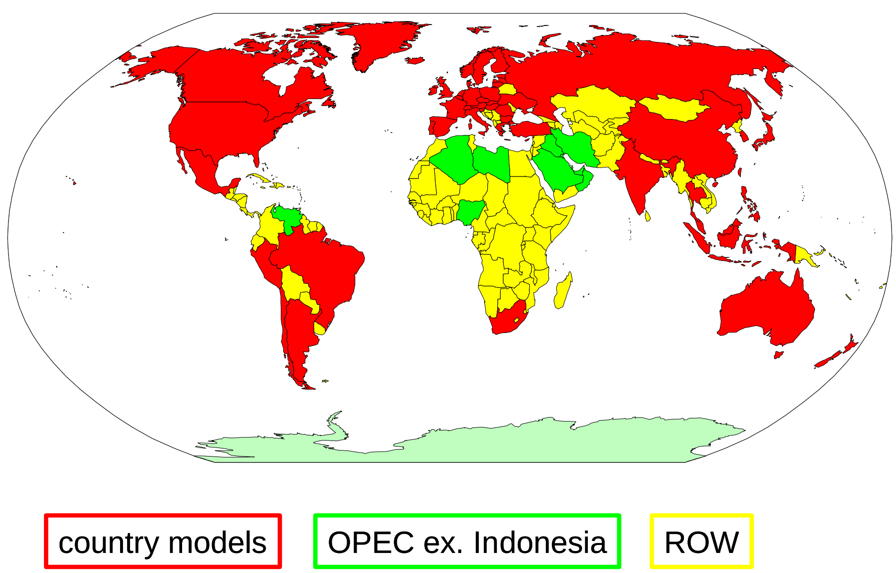
Figure 2: Data sources and coverage of GINFORS

model type		data sources	geographical coverage
trade		OECD	40 countries, 2 regions (OPEC, ROW), 25 sectors + services
country models	input-output	OECD, EUROSTAT, APERC	20 – 30 countries
	macro	OECD / IMF	53 countries
	energy	IEA	53 countries
	material	SERI	30 – 40 countries
	land-use	IIASA	20 – 30 countries

The input-output tables will be delivered for about 15 to 20 OECD countries from the OECD. EUROSTAT can deliver tables for most member countries. The tables for the accession countries and for some important Asian countries will be taken from national sources. It can be expected, that input-output tables for at least 20 to 30 countries will be available. The energy data is already given for all 53 countries with the energy balances of the International Energy Agency. The material inputs will be delivered by the Sustainable Europe Research Institute for 30 to 40 countries. Land use data for about 20 to 30 countries is prepared by IIASA.

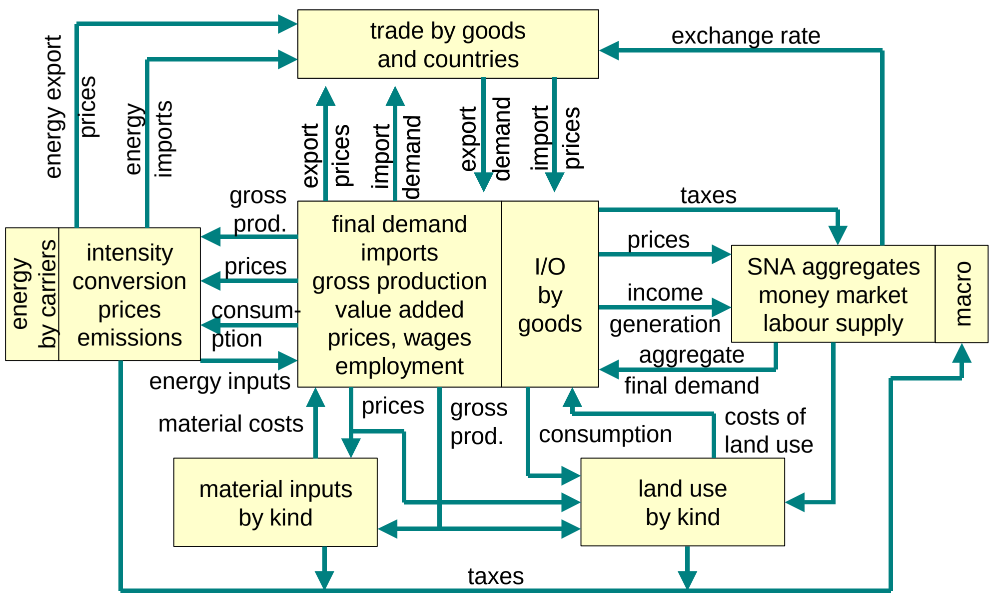
A better impression about the country coverage gives figure 3: The red areas are covered with countries, that are explicitly part of the system. The green area shows OPEC (without Indonesia, that is explicitly modelled) and the white area represents the rest of the world, ROW. This group consists of economies in Central and South America, in Asia, in Africa and very few in Europe, that play a minor role concerning GDP, trade and environmental pressure.

Figure 3: Country coverage of GINFORS



An overview of the logical structure of the system can be derived from figure 4, where *for one specific country* the interrelations between the different modules are depicted. In the centre the input-output model is situated, which takes aggregate final demand from the macro model and disaggregates it for product groups estimating share functions, that depend on relative prices. For consumption the disaggregation is first done for consumption purposes and in a next stage for product groups. The input-output model further receives vectors of export demand and import prices by product groups from the trade model. Import demand for products is calculated as part of final demand for products depending on relative prices.

Figure 4: Model structure for a specific country



With input coefficients as exogenous variables the vectors for gross production, intermediate demand and value added are calculated. Labour demand by sector in physical units depends on gross production of the sector and its real wage rate. The wage rate of each sector depends on the macroeconomic average, which is explained by the aggregate consumption price and the average productivity of labour in the economy. Sectoral profits can be calculated by subtraction of labour costs, depreciation and indirect taxes from value added.

With the unit costs by sector for labour (labour costs per unit of output) the value added prices are estimated. Using the transposed input-output conversion, the vector of value added prices and import prices explain the vector of gross production prices. The export price vector and the consumption price vector depend on the vector of gross production prices. The vector of export prices is given to the trade model, whereas the prices for consumption and investment feed as aggregates into the macro model. The vectors of gross production, consumption and its prices are drivers for the energy model, the material input model and the land use model.

The macro model takes the primary income in sector detail, aggregates it for private households, financial and non-financial corporations, government and the foreign sector, and redistributes the income between these institutions and calculates in a fully endogenized SNA system such figures as disposable income and net lending/net borrowing. Money supply is explained by a policy rule for the central bank, money demand is explained by GDP and interest rates, so that interest rates are part of the equilibrium solution of the money market. Prices are taken in sector detail from the input-output model and are aggregated for the different components of aggregate final demand.

Disposable income of private households and the government, and interest rates are important determinants for aggregate private and public consumption and aggregate investment. Domestic GDP deflator relative to the US value and the difference between the domestic interest rate and the US interest rate explain the exchange rate of the local currency against the US-Dollar.

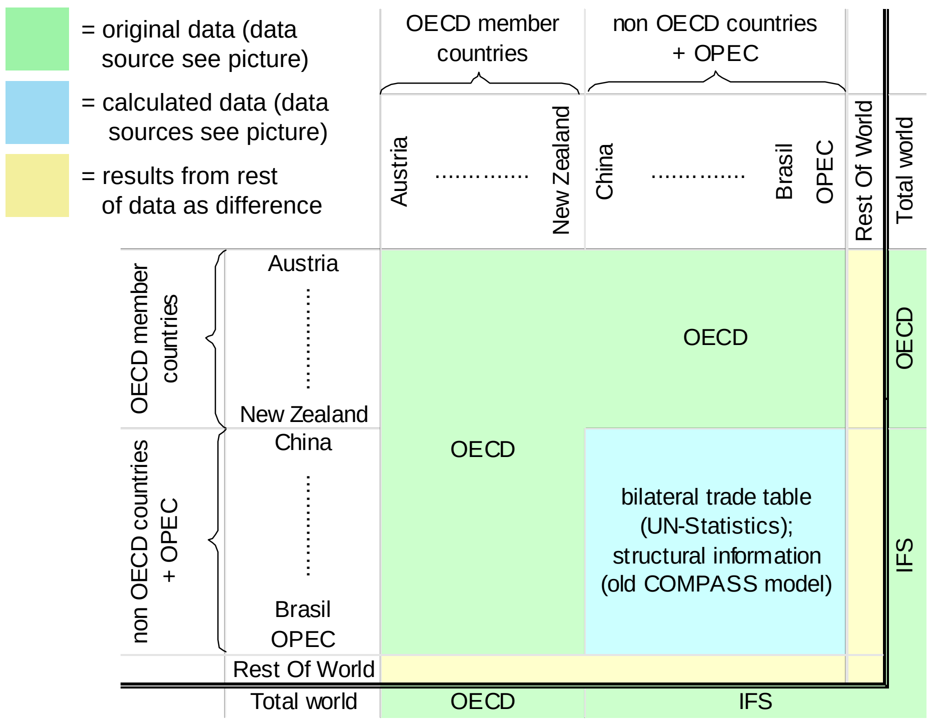
The energy model first computes for every final demand category energy intensities, that depend on the ratio of energy price to the output price of the demanding sector and (technological) time trends. Multiplication with the activity of the demanding sector (production or consumption) gives the energy demand of that sector. In the next stage, for every final demand category the shares of the different energy carriers are calculated, depending from relative prices and trends. The input coefficients for primary energy carriers in the production of secondary energy carriers are explained by relative prices and trends. The total demand for the different primary energy carriers allows for the calculation of CO_2 emissions via fixed carbon intensities. The prices of the different energy carriers are explained by gross production prices, indirect taxes minus subsidies and import prices. Energy costs feed back to the input-output model. Energy taxes are calculated, which are input for the SNA model as tax revenues of the government.

For the material model the drivers are - as already said - the vector of gross production and its price vector, which both are taken from the input-output model. A vector of material input-coefficients is calculated by dividing physical material inputs by gross production of the demanding sector, measured in constant prices of the local currency. These coefficients are determined by the price of material relative to the output price of the demanding sector and time trends. The information for material costs is given back to the input-output model. If taxes are levied on material inputs, these feed back to the SNA model as tax revenues of the government.

The modelling of the land use module is not yet finished, but it is clear, that production and consumption activities as well as their prices will be the drivers. There will also be a feed back of the cost of land use to the input-output model and in the case of taxes to the macro model.

The full statistical information to realize the just described structure will not be available for all countries. For countries with missing data, two alternatives are possible. The first is to specify a revised structure with shortcuts where data is missing. This procedure does not affect the qualities of forecast in comparison to the full specification, as reduced forms simply substitute the full specification form. The second very time consuming alternative is own data work, if data in question can not be renounced. This was the case for parts of the trade matrices of the OECD, which are not completely filled according to figure 5.

Figure 5: Bilateral trade matrix for a specific commodity in billions of US$



A bilateral trade matrix for a specific commodity i contains in the rows the exports of the delivering countries and in the columns the imports of the receiving countries. The OECD trade matrices start with the OECD countries (from Austria to New Zealand) followed by important Non-OECD countries summing up the world totals. Exports and imports for the rest of the world (ROW) can easily be calculated. But the problem is, that the trade between the Non-OECD countries is not reported in the tables. There is also no information in the tables for the world totals of the Non-OECD countries. We filled this gap using total exports and imports of the Non-OECD countries published by the IMF. Now it was only necessary to estimate the structure of the trade between the Non-OECD countries. This information we took from the trade shares of the United Nations COMTRADE database, which has also been the source of the COMPASS trade data

5 Conclusions

The model GINFORS is able to meet the demands for an instrument of the integrative analysis of sustainable development in its social, economic and environmental dimension: It is a global multicountry/multisector model, that depicts the interdependencies between social, economic and environmental development. The development of the different countries is linked by a bilateral multisector/multicountry trade model. Econometric estimation of the parameters gives a realistic picture of the agents' behaviour under conditions of bounded rationality.

Business-as-usual simulations with the model will allow for the calculation of sustainability gaps in future development, which can be the basis for the identification of strategies to avoid them. The model will be able to calculate global results for such a country specific sustainability strategy. It will be possible to show the economic, social and environmental consequences of European policy for the different European countries and the world.

The number of economic and environmental indicators, which the model offers, is rather high compared to other modelling exercises. Only the social development, that will be described by the model, will still be rather incomplete in comparison to economic and environmental indicators. The reason is missing data. Worldwide statistics are available for economic and environmental issues, such as SNA (System of National Accounts) and SEEA (System of Integrated Economic and Environmental Accounts) statistics. But up to now, there is no international data system – and only few national approaches, – that links social and economic or social and environmental data. This gap in statistics still has to be filled.

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