The GINFORS Model in the MOSUS Project:

Model Description and Baseline Projection

by

Christian Lutz[b], Bernd Meyer[a,b], Marc Ingo Wolter[b], Stefan Giljum[c]

a. Department of Economics and Business Administration, University of Osnabrück.

b. Gesellschaft für Wirtschaftliche Strukturforschung (GWS) mbH, Osnabrück.

c. Sustainable Europe Research Institute (SERI), Vienna.

Corresponding Author: Bernd Meyer, Department of Economics and Business Administration, University of Osnabrück, 49069 Osnabrück, Germany.

E-mail: bernd.meyer@uni-osnabrueck.de

Keywords: Policy Simulation, Econometric Models, Global Modelling, Resource Consumption.

Abstract

The Global INterindustry FORecasting System (GINFORS) is an economy-energy-environment model with global coverage. A bilateral world trade model links national models for 25 commodity groups and services. All EU-25 countries, all OECD countries and their major trade partners are explicitly modeled. The model is based on time series of international statistics data from 1980 to 2002. Behavioural parameters are derived from econometric estimations assuming bounded rationality of agents with myopic foresight.

Additional to detailed economic models including Input-Output Structures for the 24 most important countries, resource use is explicitly modelled. Energy-emission models are based on energy balances of the International Energy Agency. Total final energy consumption, transformation and total primary energy supply are consistently linked for 12 energy carriers to the economic driving forces that are explained in the economic part of the model. Carbon emissions result from the use of fossil fuels. Furthermore, material input models have been integrated into the system. For all countries resource use extraction in tons is explained for 6 categories. Their development is either driven by the economic part of the model or the energy model concerning fossil fuel use. Land use models (LUM) are also linked to the economic models.

The model has been completed and applied in the EU project „MOSUS“ (Modelling opportunities and limits for restructuring Europe towards sustainability). It is a comprehensive tool for monitoring trends in global resource use. Due to the global coverage and the full link to economic development on sector and national level, the model can assess impacts of policy options and economic developments on national and global resource use. The paper presents the model structure and describes the baseline

scenario of the project, which demonstrates the ability of the model to consistently project major EU sustainability indicators in a global context.

1. INTRODUCTION

The model GINFORS (**G**lobal **IN**terindustry **FOR**ecasting **S**ystem) has been developed to allow for a global analysis of the economic-environmental interdependencies as a tool for concrete policy planning. It has been used as the simulation engine in the MOSUS project (www.mosus.net), which analysed as part of 5th frame program of the EU commission the impact of European resource strategies on the economic development and resource extractions in the world and all European countries.

In the sense of Van den Bergh and Janssen (2004) it is an integrated system that adds economics to industrial ecology and thus favours policy realism. The model combines econometric-statistical analysis with input-output analysis embedded in a complete macroeconomic framework. The link between the economic development in the countries is given by international trade, which is the result of global competition in deep sectoral disaggregation. This characterization is true also for the models of the GTAP family (Hertel 1997) – to which belongs the economic-environmental-energy model GEME3 (Capros et al. 1997). A different global modelling approach has been presented by Duchin (2005). Based on given final demand, linear technologies, factor endowments and factor prices a linear program calculates output, prices and trade, which minimizes global factor costs. This optimizing solution can be characterized as Ricardian, because comparative advantage determines the results.

The GTAP models are neoclassical CGE models (computable general equilibrium) which assume perfect information of the agents and in most cases equilibrium prices. Concerning the behaviour of the agents the central hypothesis of GINFORS is that of bounded rationality: Agents do not have perfect information and perfect foresight so that they are not able to derive optimal solutions. There are always plausible alternatives for the structure of the behavioural equations of the system, which can only be selected by the empirical test of econometric estimation. Markets are imperfect, which means that prices are not given with the market clearing assumption, but by price setting behaviour of the firms like mark up pricing.

A further important difference is given with the method of parameterization: The GTAP models take elasticities from the literature and calibrate all other parameters with the information of one data point, whereas nearly all parameters of GINFORS are estimated econometrically using international time series data sets from the OECD, the IEA and the IMF. Only in some cases it could not be avoided to use national data. This was for example the case with the input-output data of China.

Econometric estimation of the parameters, bounded rationality of the agents and market imperfections are also central qualities of the European energy-economy-environment model E3ME (Barker 1997, 1999).

The model GINFORS is based on the experiences made with the development of the global energy-economy-environment model COMPASS (Meyer, Lutz 2002a, Meyer, Lutz 2002b, Meyer, Uno 1999). GINFORS can be addressed as an improved version of COMPASS using better data, better software, a different regional focus and having a focus on material consumption. For the relations between GINFORS and COMPASS see Meyer, Lutz, Wolter (2005).

The paper at hand gives in section 2 an overview of the model, in section 3 a presentation of the structure of the model. In section for we discuss the scenario for a baseline forecast which was used in the MOSUS project. In section 5 the results of the forecast are depicted. Without policy intervention global CO_2 emissions will grow with 2.1 per cent per year which means that the emissions in 2020 are 75% higher than in

1990 - the reference year of climate simulations. In section 6 some conclusions about the forecast result and further model applications close the paper.

2. THE MODEL IN AN OVERVIEW

A good impression of the country coverage of the model is provided by Figure 1: The black (red) areas are covered with countries that are explicitly part of the system. The grey (green) area shows OPEC (without Indonesia that is explicitly modeled) and the white (yellow) 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. The model is open to be extended by further countries.

Figure 1

Figure 2 provides a survey of the complete model. Within its centre, there is the trade model. For 25 commodities as well as the service trade, bilateral trade matrices for all OECD countries and ten further major trade partners are provided. Via this trade context, both quantities and prices are properly allocated to the countries. Each spoke of the wheel stands for the model structure of a certain country. The economic core of a model consists of the macro model (MM) and the input-output model (IOM). Whilst macro models by GINFORS are at hand for all countries, input-output models are available for 24 countries only. The economies of the remaining countries are solely displayed by a macro model. The energy-emission models (EEM) are based on the energy balances of the International Energy Agency (IEA) and are, therefore, available for all countries and regions as well. They picture the energy consumption structured by the relevant energy carriers. The CO_2 emissions are linked with the fossil energy carriers by constant carbon relations.

In the course of the MOSUS project (www.mosus.net), material-input models were added to GINFORS. For all the countries displayed in GINFORS, material consumptions structured by six categories are ascertained. Those are linked either with the input-output model, or, for the countries lacking an input-output model, with the macro model. For the projection of those extractions connected with fossil energy carriers, the results of the energy-emission model are referred to. Moreover, an enhancement by land-use models (LUM) is being worked at.[1]

The rings connecting the model segments land use (LUM), material input (MIM), macro model (MM) and energy emission (EEM) signify the global identity of these factors. Referring to the balance of payments, being part of the macro model, this identity can be explained particularly well. Global imports and exports, at least when ascertained in the same price concept, have to be identical. This means the demand for the consistency of the global trade and national models, a demand met by GINFORS.

Figure 2

The data base of GINFORS basically is supplied by five sources: (1) OECD, (2) the International Monetary Fund (IMF), (3) Eurostat, (4) the COMTRADE data banks of the UN and (5) the International Energy Agency (IEA). Furthermore, for two significant countries (China and Taiwan), national statistics are evaluated. The trade data resulted from a merging of OECD and UN data. The data for the macro model are based on the OECD (2004) „National Accounts of OECD Countries, Detailed Tables“

[1] A note on the use of terms: *Model* is the word for those component parts of GINFORS ascertained in particular within the wheel. *Modules* are component parts of a model.

and the data set „International Financial Statistics“ by the International Monetary Fund (IMF). Since for the model a coherent level of data is necessary (final year 2002), gaps within the data sets were filled by own calculations. In the majority of the cases, the input-output tables were taken from OECD publications and Eurostat. The energy models exclusively refer to the energy balances published by the IEA.

For the land-use models and the material-input models, the data supply by the International Institute for Applied System Analysis (IIASA) and the Sustainable Europe Research Institute (SERI) as part of the MOSUS project form the data base. The land use models are not permanently part of the system.

3. THE STRUCTURE OF THE MODEL IN DETAIL

THE BILATERAL TRADE MODEL

The Bilateral Trade Model is the core of the GINFORS model, which links the national models for 25 composite commodities and one service aggregate via the international trade. The display of the bilateral trade by services is, due to their increasing significance, an important enhancement of the approach in comparison to COMPASS. The 40 countries and 2 regions appearing as unaffiliated actors within the trade model, create demand for import in current prices in US$ and export price indices in US$ to the trade model and receive demand for export in current prices in US$ and import price indices in US$ from the trade model. The service trade model exclusively links the countries via service imports and exports.

This modelling allows both the projection of the global effects of the overall economic development of a country to all the others taking part in trade, and distinguished monitoring of certain commodities. By means of the combination with the IO models of the countries, not only the effects of changes in the demand for export of

e. g. finished products may be analyzed directly, but also the resulting trade flows of semi-finished products and primary commodities.

For each composite commodity and service, the bilateral trade model diplays the global trade in US$ completely. The export by country *a* to another country *b* equals the import of country *b* from country a. The imports of a country on the whole are the sum of its imports from all other countries.

Every national model provides import vectors *m[t]* for *i* = 25 composite commodities in national currency and export price vectors *p[t]* for 25 composite commodities as well and the exporting countries *l*. In turn, every national model receives export vectors *x[t]* and import price vectors *q[t]* for 25 composite commodities.

Dividing exports, imports and their prices in national currencies by the exchange rate (national currency/US $) yields the variables in US $ $\tilde{x}$, $\tilde{m}$, $\tilde{p}$, $\tilde{q}$. The cube of trade matrices $\tilde{T}[t]$, has the dimension *i* commodities, *l* exporters and k importers, the matrices being square, the exporting countries mentioned in the *l* rows, the importing countries mentioned in the k columns. Dividing each element of the trade matrix for a good *i* by the column sum gives the Matrix of shares *S*, which shows for a commodity *i* the share of exporting country *l* in the imports of country *k*.

Therefore, multiplying the share matrix for good *i* with the vector of imports of good *i*, gives the vector of exports of good *i*. For country *l* \`s exports of good *i* follows:

$$\tilde{X}_{i,l} = \sum_{k=1}^{42} s_{i,lk}[t] \cdot \tilde{m}_{i,k}[t] \qquad (1)$$

$\tilde{X}_{i,l}$: Nominal exports of good i of country *l* in US-Dollar

$\tilde{m}_{i,k}$: Nominal imports of good i of country *k* in US-Dollar

$S_{i,lk}$: Share of country *l* in the imports of good *i* in country *k*

In general it is assumed that the elasticity of the nominal shares on price changes is 0.5. This means that, with reference to the real market shares, the price elasticity is -0.5. Ceteris paribus, with an increase of export prices by 10% the nominal trade share increases by 5%, whilst the quantity actually traded decreases by 5%. Alternative calculations showed that the development of the international trade of the EURO countries as well as other currency regions in the years 2003 and 2004 with an elasticity of 0.5 was calculated best.

In the near future this assumption will be substituted by econometric estimations of the price elasticity for every element of the trade matrices.

$$s_{i,lk}[t] = s_{i,lk}\left(\tilde{p}_{i,l}[t]/\tilde{q}_{i,k}[t]\right) \tag{2}$$

$\tilde{p}_{i,l}$: Export price for good *i* from country *l* in US-Dollar

$\tilde{q}_{i,k}$: Import price of good *i* in country *k*

The import price of country *k* for the commodity *i* is the weighted average of the export prices of its trading partners. This means for good *i* that multiplying the transposed share matrix with the vector of export prices gives the vector of import prices, or for the importing country *k*:

$$\tilde{q}_{i,k}[t] = \sum_{l=1}^{42} s_{i,lk}[t] \cdot \tilde{p}_{i,l}[t] \tag{3}$$

THE INPUT-OUTPUT MODELS (IOM)

Input-output models are available for 24 countries, to which belong the EU15 countries without Portugal, Ireland and Luxembourg plus the new EU countries Czech Republic, Slovak Republic, Hungary and the major trade partners USA, Canada, Australia, Japan, China, Taiwan, India, Mexico and Brazil.

The OECD will publish Input-Output-tables for more non-OECD countries, so it will be possible to implement more industrial information in future versions of the model.

Since there is at the moment only one observation of the IO structures, input-coefficients can not be endogenized and are treated generally as exogenous variables. An exemption is given with the energy inputs, because the time series information of the energy balances allow for the endogenization of sectoral energy inputs.

Furthermore, time series are available for the labour input in employees as well as in currency units within the OECD statistics. These data, however, are not as deeply structured as in the input-output tables, varying between respective countries. Therefore, these factors are displayed by six combined sectors.

The structure of composite commodities is determined for exports and imports by the world trade data, so that import functions can be calculated. Regarding consumption by private households, the OECD publishes time series structured according to purposes of use. This, on the one hand, is a useful category considering the analysis of consumption patterns, yet on the other hand there is a lack of bridge matrices allowing the transfer of the purposes of consumption by economic sectors. So the structure of private consumption as well as for government consumption and capital investments, structures are kept constant or projected in scenarios by exogenous performance targets.

Omitting the country index, final demand for good i in constant prices and local currency is given with:

$$f_i[t] = c_i[t] \cdot C[t] + b_i[t] \cdot I[t] + d_i[t] \cdot G[t] + X_i[t] \quad | \quad i \in [1,\ldots,41] \tag{4}$$

f_i	Final demand
c_i, b_i, d_i :	Exogenous variables
C	Total private consumption
I	Total investment
G	Total public consumption
X	Exports

The import prices in domestic currencies $q_i[t]$, with regard to adaptation lags, result from the import price in *US$* $\tilde{q}_i[t]$ and the exchange rate *EXRA[t]*.

$$q_i[t] = q_i(q_i[t-1], \tilde{q}_i[t] * EXRA[t]) \tag{5}$$

Imports in constant prices $m_i[t]$ are a function of the relative price resulting from the import and production price $q_i[t]/p_i[t]$, measured in local currency, and the final demand $f_i[t]$ for the commodity i:

$$m_i[t] = m_i\left\{\frac{q_i[t]}{p_i[t]}, f_i[t]\right\} \tag{6}$$

The vector of real gross production *y* can now be calculated as:

$$y[t] = [I - AR[t]]^{-1} * \{fd[t] - m[t]\} \tag{7}$$

AR is the matrix of real input coefficients, which are - as already stated above - are for non-energetic inputs exogenous variables determined on the basis of assumptions concerning technological development. For the energy rows 2, 7 and 25 the input coefficients are endogenous, driven by the energy model. *I* is the unit matrix.

By means of the multiplication of all input coefficients – including the primary factors of production – by their factor prices and the summation of the different types of costs, the result is the variable unit costs. In vector terms:

$$u[t] = (AR[t] - MR[t])' * p[t] + MR[t]' * q[t] + LC[t] * w[t] + t[t] \tag{8}$$

In the process, ***MR*** is the input coefficient matrix of imports, (***AR-MR***) the domestic one. ***LC*** is the diagonal matrix of the labour input coefficients, $w_j[t]$ being the vector of wages and $t_j[t]$ the vector of net commodity taxes per unit plus depreciation.

Production prices $p_j[t]$ are determined by the companies via mark-up calculation from the variable unit costs. Exceptions only occur when, due to the homogenity of commodities in relation to the global market, the companies are not price leaders, but price takers. This basically is the case on primary commodity markets (mineral oil, natural gas, coal and ores) where, with reference to differences in quality and transport costs, a coherent global market price evolves. Export prices implemented within the bilateral trade model basically are identical to production prices.

$$p_j[t] = p_j\{u_j[t]\} \tag{9}$$

On the level of sectors, labour demand and the respective wages are ascertained for six combined economic sectors. For this purpose, the necessary explanatory factors from the input-output model are combined by aggregation in order to form these six economic sectors.

The wages are depending in a Phillips curve approach from the macro labour productivity ***Y/H***, the macro consumption price index P_c and the relation between macro employment ***H*** and population ***Pop***.

$$w_j[t] = w_j(Y/H, P_C, H/Pop) \tag{10}$$

The number of employees $h_j[t]$ is depending on production ***y***, the real wages ***w/p*** and an autonomous trend of technological progress.

$$h_j[t] = e_j\left\{y_j[t], \frac{w_j[t]}{p_j[t]}, t\right\} \tag{11}$$

The labour input coefficients $LC[t]$ result from definition as quotients of employment and gross production, whilst the wage income $l[t]$ results from the multiplication of the annual wage per employee $w[t]$ by the number of employees $h[t]$.

$$LC[t] = \frac{h[t]}{y[t]} \tag{12}$$

$$l_j[t] = h_j[t] \cdot w_j[t]$$

Operating surplus $g[t]$ can then be calculated as a residual:

$$g_j[t] = (p_j[t] - u_j[t]) \cdot y_j[t] \tag{13}$$

THE MACRO MODELS (MM)

The macro models consist of five modules: balance of payments, final demand, monetary market, labour market and the System of National Accounts (SNA).

Balance of Payments

The balance of payments collects the monetary transactions between inlanders and foreigners. All flows of the current account, such as goods exports and imports and income paid and received as well as transfers paid and received are endogenous.

Assuming flexible exchange rates, the balance of foreign exchange payments is zero and the balance of capital transactions can be calculated as a residual. The exchange rates were generally estimated as dependent on the relation of the GDP deflator of the respective country and the GDP deflator of the USA. This basically yields good results, with elasticities ranging close to 1. The approach taken is basically the only possibility of long run projections of the exchange rates up to the year 2020. Differences in the change of prices, as a consequence, result in varying nominal exchange rates. Exceptions to this rule are the EURO and the YUAN, which are exogenous variables.

The model consistently links the balances of payments of the single countries. This quality, extremely important for the significance of the applications of the model, is achieved by the consistent collection of the balance of payments for the region „Rest of the World“ within the model. Commodity and service exports and imports can be collected directly from the trade matrices. With the income flows and transfers, it needs to be considered that on a global scale, the sum of the incoming flows must equal the sum of the outgoing ones. Since the region „Rest of the World“ mainly consists of developing countries, it may well be assumed that the drain of income and transfer is zero. As a consequence, the incoming flow of income or transfers of the region „Rest of the World“ has to be the respective difference of the sum of the outgoing and the sum of the received income or transfers of the explicitly monitored countries

Final Demand

All components of final demand are endogenous variables and mainly explained by income figures. Interest rates play only a minor role. Population, next to GDP, is one important determinant for public consumption. Prices of the different components of final demand are estimated by aggregated prices from the input-output model. If there is no input-output model, aggregated labour unit costs explain aggregated macro prices. Import demand is an aggregate of sectoral imports which are determined in the input-output model. If the country has got no input-output model, an aggregated import function is estimated with GDP and the relative import price serving as determinants. The vector of import prices in US$ is given by the trade model. It is transformed into a vector of import prices in local currency by multiplication by the exchange rate. By aggregation, a price for total imports can be calculated.

Monetary Market

A reduced form of money market equilibrium is estimated in which the government bond yield is explained by the discount rate and GDP. The discount rate is explained as a policy rule by the rate of inflation. For the countries of the EURO area, the interest rates are exogenous, since there are not enough observations for econometric estimations.

Labour market

Labour supply, measured as labour force, is dependent on the development of population, which is exogenous according to the UN (2005) forecast. Labour productivity, defined as the ratio of real GDP and employment, is dependent on the real wage rate and technological trends. Labour demand, i.e. employment, can be calculated by multiplying the inverse of labour productivity by real GDP. The aggregated wage rate is dependent on labour productivity and the development of consumer prices. For countries with input-output models, labour demand and wage determination is described for six sectors, which are consistently linked with the 41 sectors of the input-output model. A detailed discussion of the disaggregated labour demand modeling can to be found below in the description of the input-output model. Unemployment is explained by the difference between labour force and employment.

System of National Accounts (SNA)

The SNA modules in short display the macroeconomic accounting of a country. Their prime objective is the ascertaining of available income and financial accounts for the private sector and government. The available income, being a determinant of demand for consumption, is a significant factor, the financial accounts – first and foremost those of the government – are significant target factors of economic policy. Within the centre, there are functions made up to explain taxes and further revenues on the side of the government and the government transfer payments to the private sector, including, of course, redistribution by social security systems.

The Energy Emission Models (EEM)

The energy emission models show the interrelations between economic developments, energy consumption and emissions. For this purpose, the variables of the corresponding macro model and of the IO Model – if available – are used as drivers. Vice versa, the expenditure for energy consumption has a direct influence on economic variables. The data basis of the energy models are uniform energy balances in physical units drawn up by the International Energy Agency (IEA 2004) which have been available for each year from 1960 resp. 1970 on. The CO_2 emissions which are connected with the Total Primary Energy Supply (TPES) via fixed emission factors are also recorded by the IEA

Final Energy Consumption *fe* of sector *j* is explained by the output *y* and the relation of the aggregate energy price *pe* – an average of the different carrier prices weighted with their shares in the energy consumption of that sector – and the sector price *p*.

$$fe_j[t] = fe_j\left(y_j[t],\ pe[t]/p_j[t], t\right) \tag{14}$$

If a country does not have an input-output model, GDP is taken instead of the sectors output and the sector price is exchanged by the GDP deflator.

Final demand of energy carrier *i* can be calculated by definition, multiplying the share of carrier *i* in the energy demand *cf* of sector *j* with final energy demand of sector *j* and summing up over all *n* sectors.

$$cf_i[t] = \sum_{j=1}^{n} cfc_{i,j}[t] \cdot fe_j[t] \tag{15}$$

$cfc_{i,j}$: Input coefficient for carrier *i* in final energy demand for sector *j*

For residential and selected important energy consuming sectors these shares are depending from the relation of the carriers' price and the aggregated energy price.

$$cfc_{i,j}[t] = cfc_{i,j}\left(pe_i[t]/pe[t], t\right) \tag{16}$$

For other sectors the carriers shares are exogenous.

Conversion from primary energy into final energy takes place for electricity (i = 11) and petroleum products (i = 3). The demand of carrier i for conversion cc is given multiplying the production of the secondary energy carrier in question cp with the input coefficient ccc of primary energy carrier i:

$$cc_{i,11}[t] = ccc_{i,11}[t] \cdot cp_{11}[t] \tag{17}$$

$ccc_{i,11}[t]$: Input coefficient of carrier i in the production of electricity

The input coefficients of primary energy carrier i are explained by the relation between the price of the carrier and the price of the converting sector, which is taken from the input output model (sector 25 in the case of electricity and 7 in the case of petroleum products).

$$ccc_{i,11}[t] = ccc_{i,11}(pe_i[t]/p_{25}[t], t) \tag{18}$$

$$cc_{i,3}[t] = ccc_{i,3}[t] \cdot cf_3[t] \tag{19}$$

$$ccc_{i,3}[t] = ccc_{i,3}(pe_i[t]/p_7[t], t) \tag{20}$$

$ccc_{i,3}[t]$: Input coefficient of carrier i in the production of petroleum products

The exports of carrier i are calculated multiplying the share es of the country in question in country k`s imports with country $k$`s imports of that carrier and summing up over all 42 countries of the trade system. For this purpose the trade matrix of product group 2 – mining and quarrying – is disaggregated into the different fossil fuels.

Carrier demand, exports:

$$cx_i[t] = \sum_{k=1}^{42} es_{i,lk} \cdot cm_{i,k}[t] \tag{21}$$

$es_{i,lk}$: Share of country *l* in the imports of country *k* of energy carrier *i*

The import of carrier *i cm* is calculated as a fixed share of total carrier demand *cf* plus *cc*:

$$cm_i[t] = cm_i(cf_i[t] + cc_i[t]) \tag{22}$$

Production of energy carrier *i* can then be calculated by definition:

$$cp_i[t] = cf_i[t] + cc_i[t] + cx_i[t] - cm_i[t] \tag{23}$$

Total energy carrier supply *cs* is the sum of production *cp* and imports *cm*:

$$cs_i[t] = cp_i[t] + cm_i[t] \tag{24}$$

Based on total supply of the different fossil fuels and their carbon per physical unit, the emissions of CO_2 can be calculated.

The price indices of fossil fuels crude oil, gas and coal are exogenous world market prices, which drive the country specific end-use prices of these carriers *pe*, which additionally are affected by taxes:

$$pe_i[t] = pe_i(v_i[t]) \tag{25}$$

v_i : world market prices for coal, gas, crude oil in local currency.

For secondary energy carriers electricity and petroleum end use product prices are driven by the related prices from the input-output model:

electricity: $pe_{11}[t] = p_{25}[t]$ (26)

mineral oil: $pe_3[t] = p_7[t]$ (27)

The measured parameters reflect also the historically given taxes. For forecasts and simulations additional or multiplicative factors can be used to introduce tax policies. In an improved version of the model, which is just under construction, all domestic energy carrier prices will be absolute prices measured in local currency per physical unit. This will allow adding taxes in local currency per physical unit to get an extract distinction between produal prices and consumer prices.

THE MATERIAL-INPUT MODELS (MIM)

The modelling of material extraction for coal, crude oil, gas, biomass, ores and other materials has to guarantee, that the global economic drivers are linked with the resource extraction in the different countries. It is only necessary to identify the dependency of materials from export and from domestic demand. If this is done, international trade and domestic production, which is also linked with trade, will drive material extraction in a globally consistent way following the global economic development.

For the extraction of materials coal, crude oil and gas the production figures are taken as drivers, which for each of them are given in physical terms from the energy models. Since the energy models are calculating in detail the determinants of production as domestic demand, imports and exports, the impact of exports of these materials on the extraction is automatically given. But there have been problems to get the international trade linkage, because in the categories of the trade model, coal, crude oil and gas belong to the product group “mining and quarrying“, which includes everything that is extracted. Using UN- trade data, sub-matrices for coal, crude oil and gas could be calculated to get a precise modelling of international trade for these product groups.

For biomass it is known, that agriculture is the extracting sector. So for the countries with input- output models and bilateral trade the production of this sector in local currency in constant prices is the driver for extraction of biomass. Since here also production is depending from domestic demand and exports we also have automatically the right dependency of extraction from exports.

For countries without input-output models we do not have the information about production of agriculture, but the export figures for agriculture are there from the trade model, which can be used for driving the exports of extracted biomass. Extracted biomass, which is domestically used, is driven by GDP. For some countries which do not have input-output models and that are not part of the bilateral trade model only GDP can be used as a driver for the extraction of biomass.

For metal ores the data situation is even worse than in the case of fossil fuels, because here the extracting sector is only a part of the sector “mining and quarrying” of the input- output- model, and there is no alternative to explain the production of metal ores in the model. So we use the information about the demanders of metal ores, which are the sectors “iron and steel” and “non-ferrous metals”. Their production can be aggregated in money terms to “metal production”. Countries with input-output models are representing about 90% of world metal production. We explain with the metal production in local currency and constant prices the local metal production in tons, aggregate over all countries and drive with this figure world extraction of metal ores. With the regional structure of the year 2002 the figures for the extracting countries can be calculated.

In the case of other materials, which are more or less non-metallic minerals, we have assumed, that trade has no important influence on extraction. Thus, for countries with input-output models extraction of other materials can be explained by production of non metallic mineral products. For the other countries the drivers are GDP in constant prices.

Resource productivities for fossil fuels are endogenously estimated in the energy models. For the other resources the problem occurs that prices, which would be needed to identify cost pressure as a determinant of productivity growth, are not available for the different countries. Therefore for biomass, metal ores and other non metallic minerals productivity growth rates are exogenously given in relation to the historic trends.

4. A Forecast of Global Material Consumption: The Scenario

The description of the model has shown that it is a global system which links on the sector and the country level energy demand with economic development. The model does not include information about reserves of fossil fuels and other determinants of energy supply. So the international prices for crude oil, gas and coal are exogenous, whereas the prices for secondary energy carriers like electricity and mineral oil products can be estimated endogenously in the input-output models. Of course, the forecast of the oil price is a crucial exercise, because there are diverging ideas about reserves and production capacities. Furthermore the political instabilities in oil producing areas induce speculative bubbles.

When in spring 2005 the baseline scenario in the MOSUS project was created, the forecast of the World Energy Outlook 2004 (IEA 2004) for the oil price was taken which starts with 37.4 US$ in 2005 and reaches more or less linearly US $ 51.0 in 2020. The dramatic development of the oil price during the year 2005 was the impulse to establish at the end of the year a second baseline called ”high oil price” which is starting with US $ 56 in 2005 and growing linearly to US $ 76.5 in 2020. The paper at hand presents this “high oil price” scenario.

For gas and coal it is assumed that their nominal prices rise by about 4.0% in the average per year, because it seems to be plausible that the relation between the oil price and the prices of the other fossil fuels which rose tremendously during the years of the oil price shock, will at least partly find back to old terms. For biomass and other renewable energy carriers no additional policy efforts to raise their shares are assumed to show future “business as usual” developments without policy intervention.

Population development in the countries including migration was taken from the current UN (2005) projection. The world total for 2020 is 7.577 billion people. The global growth rate in the year 2002 was 1.2%, it will fall continuously to 0.9% in the year 2020.

As already mentioned in the description of the model, most exchange rates are endogenous variables driven by the relative prices of the countries with elasticity 1, so that the real exchange rates remain constant. Exclusions have been made for the YUAN and the EURO. These two important exchange rates are exogenous variables. In the case of the YUAN the argument is that the YUAN is not driven by market forces. The Chinese government defines the relation to the US $. We assume that this relation is kept constant. In the case of the EURO we know that this important exchange rate is driven by market forces, but we do not have enough observations to test some hypothesis empirically. So it is an exogenous variable. In the forecast it is assumed that the relation between the EURO and the US $ rises continuously from 0.80 in 2005 to 1 in 2020.

5. A FORECAST OF GLOBAL MATERIAL CONSUMPTION: THE RESULTS

The data base of the model ends in 2002. So we take this year as the reference for our forecasts for the period till the year 2020. The model calculates all variables year by year, but for a better overview we restrict our view to the historic values in 2002 and the end year 2020 of the forecast period.

The model forecasts a differentiated picture for the economic development of 53 countries, which is aggregated for the purpose of this presentation of the model to the growth rates of GDP in constant prices for some selected countries. Table 1 shows the annual average growth rates for the USA, Japan, Germany, France, China and India. After a decade (1992 – 2002) of rather low growth, Japan will find back to a reasonable annual average growth rate of 2%. For the United States the long run growth rate will reduce a bit from 3.1% (1992 – 2002) to 2.6% (2002 – 2020). For Germany there will be a slight improvement from 1.2% (1992 – 2002) to 1.4% in the forecast period. France will have a slight reduction of its long run growth rate from 1.9% (1992 – 2002) to 1.7% for the period 2002 – 2020. China will experience a reduction of its tremendous annual average historic growth rate of 9.1% (1992 – 2002) to 6.4% for the average of the period 2002 to 2020. Also for India the model calculates a small reduction of the long run growth rate from 5.9% to 4.7% for the forecast period.

Table 1

An aggregation of GDP figures measured in different currencies simply by using the exchange rates is highly problematic. Also the calculation of country aggregates in different currencies using PPP`s (purchasing power parities) is not without problems especially if the data of rich and poor countries are aggregated. So we do not calculate world totals for GDP and also not for country aggregates like “other countries” in Table 1.

Table 1 further shows the annual average growth rates for labor productivity. The forecast for the industrialized countries USA, Japan, France and Germany lies in a small range between 0.9% and 1.8% per year. The emerging economies China (5.4%) and India (2.6%) have a much higher productivity growth. The – compared with China – relative low growth of labour productivity in India may be induced by the higher population growth rate in India. In general there is a positive correlation between population and employment, and in all countries except Germany the growth of employment is greater than the growth of population.

Table 2 gives the average annual growth rates for the period 2002 – 2020 for total material extraction (used and unused) of different kind. The extraction of all different materials will grow, in the total average with 2.2% per year. Metal ores have the strongest rate with 3.5%, because this material is especially needed for the construction of the capital stock in the developing countries. Other non-metallic minerals are important for the development of infrastructures like streets and buildings and have also a growth rate (2.4%) above the average. Crude oil extraction will grow with the same rate, which is driven to a large extend by growing mobility demand in developing countries. Biomass extraction will grow a bit faster than population. A comparison between the growth of total extraction and population shows that on average only half of the total extraction growth (2.2%) is driven by population growth (1.1%). Per capita extraction of materials will grow with 1.1% per year. Also the comparison with GDP growth shows that there will be no clear decoupling of global resource demand.

Table 2

The regional structure of extractions shows high concentrations, which is well known for the fossil fuels oil, gas and coal. The remaining or even growing concentrations may be one of the reasons for global political instability. The growing importance of metal ores with growing concentration in the future is described in Table 3.

Table 3

At the moment only 8 countries extract 77% of global metal ore supply, in the year 2020 this share will be 87%. The USA will lose importance as supplier of ores (2002: 18.1%, 2020: 12.7%), whereas Indonesia, Chile and Peru will win market shares. In the year 2020, China and Indonesia alone will supply nearly one third of the world extraction of metal ores. Another centre of metal ore extraction of growing importance is South America.

6. CONCLUSIONS

The baseline forecast gives a picture of a thinkable future which shows a tremendous sustainability gap concerning global resource consumption. The demand for metal ores will have the greatest growth rates, which gives the expectation that the shortages during the last years may not have been a singular event. The question of reserves of all materials will be of growing importance in the future.

The model GINFORS will be used in the future as an instrument to analyze the impact of national and international dematerialization policies on global material extraction. First results could be achieved in the MOSUS project (Giljum et al. 2006).

Different scenarios of well designed environmental policies can achieve a win-win result for the economy and the environment, which means that environmental policies can help to reach the targets of the Lisbon strategy.

7. REFERENCES

Barker, T. (1997): Taxing Pollution Instead of Jobs: In: Ò Riordan, T. (ed.): Ecotaxation. London.

Barker, Terry (1999): Achieving a 10% cut in Europe's carbon dioxide emissions using additional excise duties: coordinated, uncoordinated and unilateral action using the econometric model E3ME, Economic Systems Research, Vol. 11, No. 4: 401-421.

Capros, P., Georgakopoulos, T., Zografakis, S., Van Regemorter, D., Proost, S. (1997): Coordinated versus uncoordinated European Carbon Tax. Solutions analysed with GEM – E3 linking the EU-12 countries. In: Proost, S. (ed.): Economic Aspects of Environmental Policy.

Duchin, F. (2005): A World Trade Model Based on Comparative Advantage with m Regions, n Goods, and k Factors. In: Economic Systems Research, Vol. 17, No. 2. pp. 141-162.

Giljum, S., Behrens, A., Hinterberger, F., Lutz, C., Meyer, B. (2006): Modelling scenarios towards a sustainable use of natural resources in Europe. Paper presented at the Berlin Conference on the Human Dimensions of Global Environmental Change. Berlin, 17.-18. November.

Hertel, T. W. (ed.) (1997): Global Trade Analysis. Modeling and Applications. Cambridge University Press.

IEA (2004): IEA Statistics Energy Balances of OECD Countries 2001-2002, Paris.

Meyer, B., Uno, K. (1999): COMPASS – Ein globales Energie-Wirtschaftsmodell, in: ifo-Studien, 45, pp. 703-718.

Meyer, B., Lutz, C. (2002a): IO, macro-finance, and trade model specification. In: Uno, K. (ed.): Economy-Energy-Environment Simulation: Beyond the Kyoto Protocol. Dordrecht, Boston, London, pp. 55-68.

Meyer, B., Lutz, C. (2002b): Endogenized trade shares in a global model. In: Uno, K. (ed.): Economy-Energy-Environment Simulation: Beyond the Kyoto Protocol. Dordrecht, Boston, London, pp. 69-80.

Meyer, B., Lutz, C., Wolter, I. (2005): Global Multisector/Multicountry 3-E Modelling: From COMPASS to GINFORS. In*:* Revista de Economia Mundial. Vol. 13, pp. 77-97.

Van den Bergh, J. C. J. M., Janssen, M. A. (2004): Introduction and Overview, In: Van den Bergh, J. C. J. M, Janssen, M. A. (ed.): Economics of Industrial Ecology. Materials, Structural Change, and Spatial Scales. MIT Press, Cambridge and London.

United Nations (2005): World Population Prospects: The 2004 Revision. http://esa.un.org/unpp/.

Figure 1: Country Coverage of GINFORS

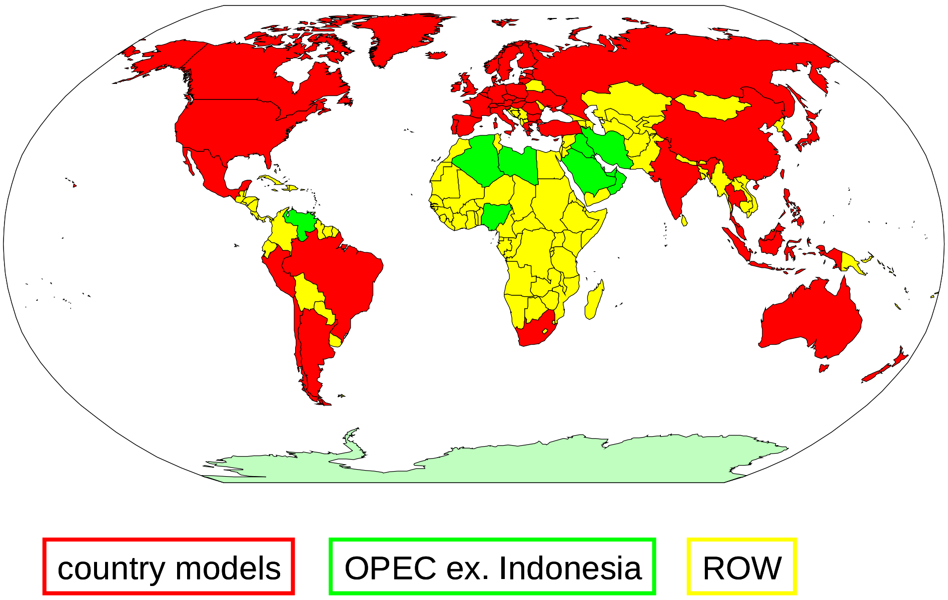

Figure 2: The Wheel of GINFORS

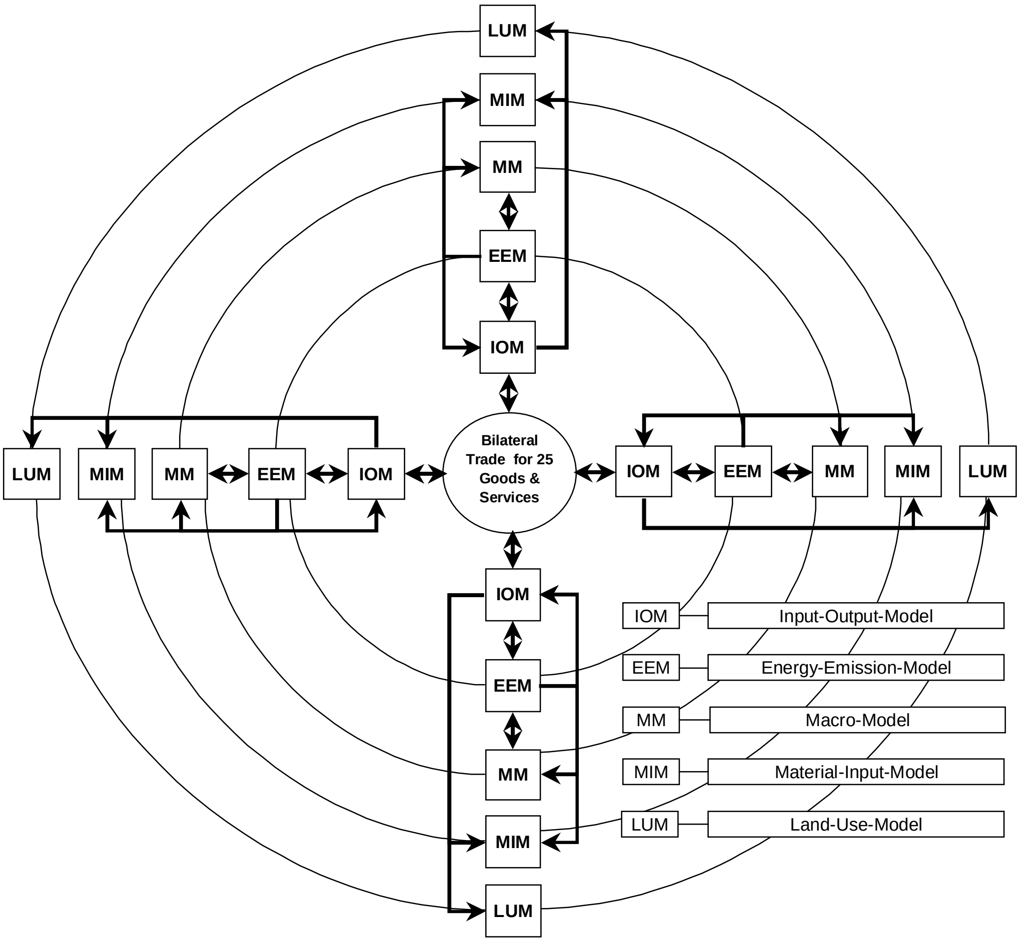

Table 1: Economic and Labour Market Developments in Selected Countries. Average Annual Growth Rates in the Period 2002-2020

	Growth rates in %			
	GDP[1995]	Labour Productivity	Employment	Population
USA	2.6	1.5	1.1	0.9
Japan	2.0	1.8	0.2	-0.1
France	1.4	0.9	0.5	0.3
Germany	1.2	1.2	0.0	0.0
China	6.1	5.4	0.7	0.5
India	4.8	2.6	2.2	1.3

Table 2: Total Global Material Consumption in Tons and World Population. Average Annual Growth Rates in the Period 2002-2020

	Growth rates in %
Biomass	1.5
Hard Coal	1.6
Cruide Oil	2.4
Natural Gas	2.1
Metal Ores	3.5
Other Non-metallic Minerals	2.4
Total Extraction	2.2
Population	1.1

Table 3: Regional structure of Metal Ore Extraction in p.c. in 2002 and 2020

	2002	**2020**
USA	18.1	12.7
Australia	7.4	8.8
Russia	3.4	3.0
China	14.0	14.0
Indonesia	12.5	17.6
Brasil	4.8	4.0
Chile	10.9	15.3
Peru	5.9	8.3
other countries	23.0	16.3
	100.0	100.0