Resource productivity, environmental tax reform and sustainable growth in Europe

The GINFORS Model
Model Overview and Evaluation

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2.2.2007

petrE (see http://www.petre.org.uk/papers.htm) is part of the Anglo-German Foundation research policy initiative: *Creating sustainable growth in Europe* (see http://www.agf.org.uk/currentprogramme/CreatingSustainableGrowthInEurope.php)

Contents

1 INTRODUCTION

The model GINFORS (**G**lobal **IN**terindustry **FOR**ecasting **S**ystem) has been developed 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 framework 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.

According to 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 developments 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 the economic-environmental-energy model GEME3 (Capros et al. 1997) belongs. A different global modelling approach has been presented by Duchin (2005).

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, e.g in the case of the input-output data of China.

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 seen as an improved version of COMPASS using more comprehensive data, enhanced software, a different regional emphasis and additionally focusing on material consumption. For the relation between GINFORS and COMPASS see Meyer, Lutz, Wolter (2005).

The paper at hand starts with an overview of the GINFORS model in section 2 and continues with presenting the structure of the model in section 3. In section 4 we shortly evaluate the model discussing its weaknesses and strengths.

2 OVERVIEW OF THE MODEL

A good impression of the country coverage of the model is provided by Figure 1: The black (red) areas are those countries that are explicitly part of the system. The grey (green) area corresponds to the OPEC (without Indonesia, which is explicitly modelled) 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 to further countries.

Figure 1: Country Coverage of GINFORS

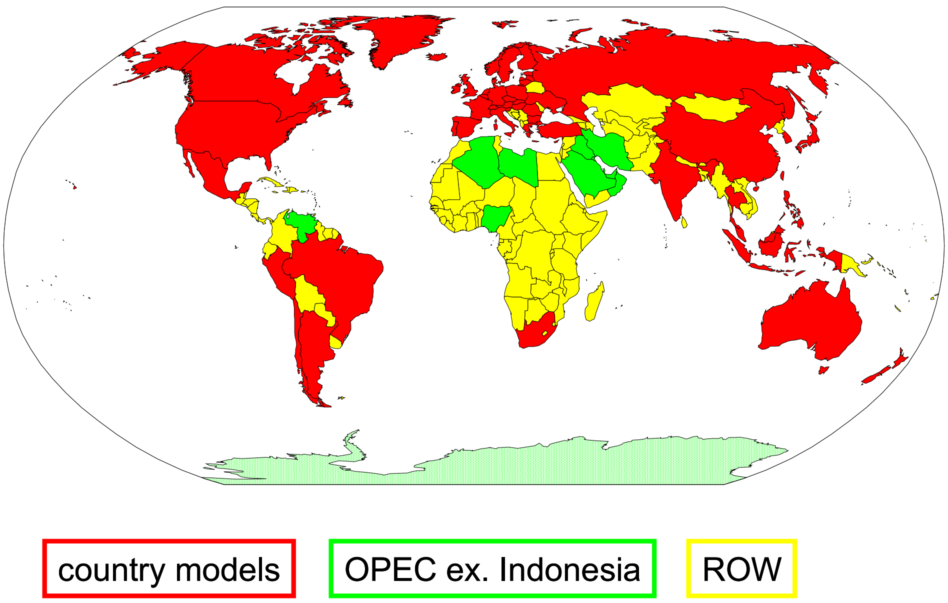
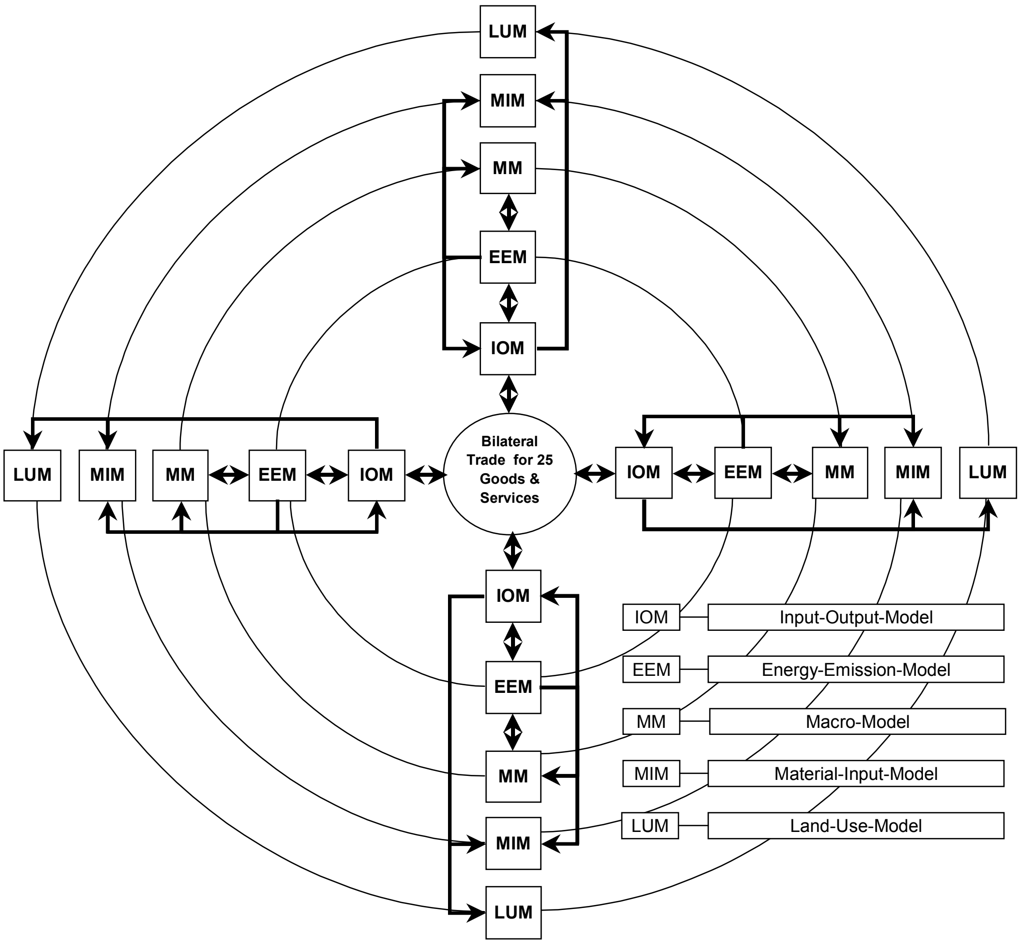


Figure 2 provides a survey of the complete model. The central part of the model is the trade model. Bilateral trade matrices are provided for 25 commodities as well as service trade covering all OECD countries, EU-25 and sixteen further major trade partners. Via this trade context, both quantities and 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 21 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. 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 determined. 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 associated with fossil energy carriers, it is referred to the results of the energy-emission model.

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 requires consistency of global trade and national models, a demand met by GINFORS.

Figure 2: The Wheel of GINFORS



The data base of GINFORS uses basically 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 results from a merging of OECD and UN data. The data for the macro model are based on the OECD „National Accounts of OECD Countries, Detailed Tables“ and the data set „International Financial Statistics“ by the International Monetary Fund (IMF). Since a coherent level of data is necessary for the model, gaps within the data sets are 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 correspond to the energy balances published by the IEA.

For land-use models and material-input models, the data supply of 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

3.1 Bilateral Trade Model

The 50 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. Every national model provides import vectors $\mathbf{m}(t)$ and export price vectors $\mathbf{p}(t)$ for 25 composite commodities and one service product in national currency. In turn, every national model receives export vectors $\mathbf{x}(t)$ and import price vectors $\mathbf{q}(t)$ for 25 composite commodities and one service good.

Dividing exports, imports and their prices in national currencies by the exchange rate (national currency/US \$) yields the variables in US \$, i.e. $\tilde{x}, \tilde{m}, \tilde{p}, \tilde{q}$. The cube of trade matrices $\tilde{\mathbf{T}}(t)$ has dimensions 26x52x52 (25 composite commodities + 1 service good, indexed by *i*, *52* exporters (rows) and importers (columns) indexed by *l* and *k*). Dividing each element of the trade matrix for a good *i* by the column sum gives the matrix of shares $\mathbf{S}(t)$, which shows for a commodity *i* the share of exporting country *l* in the imports of country *k*.

Therefore, multiplying the share matrix of good *i* with the vector of imports of good *i* gives by definition the vector of exports of good *i*. For country *l*'s exports of good *i* it follows:

$$\tilde{x}_{il} = \sum_{k=1}^{52} s_{ilk}(t)\tilde{m}_{ik}(t) \qquad (1)$$

The trade share of country *l* in the imports of good *i* in country *k* depends on the relation between the export price of country *l* and the weighted import price of country *k* and on time trends:

$$s_{ilk}(t) = s_{ilk}\{\tilde{p}_{il}(t)/\tilde{q}_{ik}(t), t\} \qquad (2)$$

where $\tilde{p}_{il}$ is the export price for good *i* from country *l* in US dollars, $\tilde{q}_{ik}$ gives the import price of good *i* in country *k*, and where the notation $z\{v\}$ indicates that *z* is a function of *v*. The import price of country *k* for 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*:

$$\tilde{q}_{ik}(t) = \sum_{l=1}^{52} s_{ilk}(t)\tilde{p}_{il}(t) \qquad (3)$$

3.2 Input-Output Models

Since there is only one observation of the input-output (IO) structures, input coefficients cannot be endogenized by econometric estimation of parameters and are treated as exogenous variables. Furthermore, time series are available for the labour input measured 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 for exports and imports is determined by the world trade data, so that import functions can be calculated. Export data are generated by the trade model.

Regarding consumption of private households, the OECD publishes time series structured according to the purpose 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. In the case of energy demand of private households it is possible to use the information of the energy model. The energy balances do not provide directly energy demand of private households, but it is possible to identify with "residential" the major component of it. Multiplication of the physical units with prices yields the monetary demand. This variable is the driver for the different energy product groups of private consumption, which have a constant structure. The non-energy demand of private households is given as a residual subtracting monetary energy demand from total private consumption. The different non-energy product groups have a constant structure. So a simple two-stage approach is applied, which allows to depict the effect of rising monetary energy demand on consumption of the other product groups, which has to be reduced.

The structure of government consumption and investment demand by goods, is kept constant or projected in scenarios by exogenous performance targets.

The import prices in domestic currencies $q_i(t)$, with regard to adaptation lags, result from the import price in US$ and the exchange rate. Imports at constant prices $m_i(t)$ (the index of countries is dispensed in order to ensure lucidity) depend on the relative price resulting from import and production price $q_i(t)/p_i(t)$, measured in local currency, and the final demand $f_i(t)$ for commodity *i*:

$$m_i(t) = m_i\{q_i(t)/p_i(t); f_i(t)\} \qquad (4)$$

A is the matrix of input coefficients defined as the relation between the factor input of the production of sector *i* and the output of the economic sector *j*. The energy rows of the **A** matrix are linked with the energy model, meaning that the input coefficients of row 7 (coke and refined petroleum) and 25 (electricity and gas) are endogenous. Further all coefficients that are important for material inputs are dependent from relative prices. The price elasticities are taken from the German model PANTA RHEI, which is based on time series of input- output- tables. All other input coefficients are exogenous variables kept constant or determined on the basis of assumptions concerning technological development. ***I*** is the unit matrix, **y** is the vector of the gross production at constant prices, which is given by:

$$\mathbf{y}(t) = [\mathbf{I} - \mathbf{A}(t)]^{-1}[\mathbf{f}(t) - \mathbf{m}(t)] \qquad (5)$$

Multiplication of the input coefficients of the variable production factors by their factor prices and the summation of the different types of costs, yields the variable unit costs. In vector terms:

$$\mathbf{c}(t) = [\mathbf{A}(t) - \mathbf{M}(t)]'\mathbf{p}(t) + \mathbf{M}(t)'\mathbf{q}(t) + \hat{\boldsymbol{\mu}}(t)\mathbf{w}(t) + \boldsymbol{\tau}(t) \qquad (6)$$

where **M** is the input coefficient matrix for imports and $(\mathbf{A} - \mathbf{M})$ the domestic one. $\hat{\boldsymbol{\mu}}$ is the diagonal matrix of labour input coefficients, **w** the vector of wages and $\boldsymbol{\tau}$ the vector of net commodity taxes per unit.

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 homogeneity of commodities in relation to the global market, the companies are not price leaders, but price takers. This is basically the case in 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 used within the bilateral trade model are basically identical to production prices.

$$p_j(t) = p_j\{c_j(t)\} \quad (7)$$

On the level of sectors, labour demand, respective wages and capital investment are determined for six combined economic sectors. For this purpose, the necessary explanatory factors from the input-output model are combined in order to form these six economic sectors. The wages in the economic sectors, defined as the annual wages per employee, result from a 'shift-share' regression with the average wage $\overline{w}(t)$, which in turn is the result of a Phillips curve with reference to the labour market situation.

$$w_j(t) = w_j\{\overline{w}(t)\} \quad (8)$$

The number of employees $e_j(t)$ depends on production $y_j(t)$, real wages $w_j(t)/p_j(t)$ and an autonomous trend of technological progress, i.e.

$$e_j(t) = e_j\{y_j(t); w_j(t)/p_j(t); t\} \quad (9)$$

The labour input coefficients are given by definition as quotients of the employment and the gross production, whilst the sum of wages results from the multiplication of the annual wage per employee by the number of employees.

Gross capital investment i is explained by the real interest rate r-π (r: nominal interest rate, π: rate of inflation) and gross production y:

$$i_j(t) = i_j\{y_j(t); r(t) - \pi(t)\} \quad (10)$$

3.3 Macro Models

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

The model consistently links the balances of payments of the single countries. This quality, important for the significance of 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. This is guaranteed because the balances for income and transfers of the region ROW are given as residuals.

The modules for the System of National Accounts (SNA) display the macroeconomic accounting of a country. Their prime objective is the determination of disposable income and financial accounts for private sector and government. The disposable income, being a determinant of demand for consumption, is a significant variable as well as net lending for the calculation of budgetary constraints.

All components of GDP are endogenous variables. Private consumption depends on disposable income; public consumption is explained by GDP and population. .Gross capital formation and imports are estimated in the input- output models and are given as aggregates by definition. If the country has no input-output model, an aggregated import function is estimated with GDP and the relative import price serving as determinants. Exports are calculated by the trade model in sector detail and are aggregated for the macro models.

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. 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 multiplying with the exchange rate. By aggregation, a price for total imports can be calculated.

With respect to the monetary market, a reduced form of 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.

On the labour market, the supply – measured as labour force – is dependent on the development of population, which is exogenous according to the UN (2005) projection. 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 modelling can be found above in the description of the input-output model. Unemployment is the difference of labour force and employment.

3.4 Energy Emission Models (EEM)

The energy emission models show the interrelations between economic development, 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 that are made available by the International Energy Agency (IEA 2006a, 2006b) 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 (2006c).

Final Energy Consumption *fe* of sector *j* is explained by the output *y*, 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*. Concerning the price dependency alternative lag structures have been tested.

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

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, services, manufacturing and steel production these shares are depending on the relation of the carriers' price and the aggregated energy price of that sector or on or from relative energy carrier prices.

$$cfc_{i,j}(t) = cfc_{i,j}\{pe_i(t)/pe_j(t)\} \tag{16}$$

For traffic sectors the carriers shares are exogenous. Biofuel shares depend on policy targets.

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 average energy input price of the converting sector. Alternatively the significance of specific carrier price relations has been tested.

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

$$cc_{i,3}(t) = ccc_{i,3}(t) \cdot cf_3(t) \tag{19}$$

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

$ccc_{i,3}(t)$: *Input coefficient of carrier i in the production of petroleum products*

The exports of carrier *i* are calculated multiplying the shares of the country in question in country *k*`s imports with country *k*`s imports of that carrier and summing up over all 50 countries and the two regions of the trade system. For this purpose the trade matrix of product group 2 – mining and quarrying – is disaggregated into the different fossil fuels.

$$cx_i(t) = \sum_{k=1}^{52} es_{i,lk} \cdot cm_{i,k}(t) \tag{21}$$

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

The import of carrier *i*, cm_i, 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:

$$cp_i(t) = cf_i(t) + cc_i(t) + cx_i(t) - cm_i(t) \tag{23}$$

For some countries, especially those with low reserves in relation to current production (for example crude oil in the United Kingdom), an exogenously given supply path is assumed, and equation 23 is solved to calculate the imports. 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 *pe* of these carriers, available for electricity generation, industry and households, which additionally may be 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: $$pe_{11}(t) = p_{25}(t) \tag{26}$$

mineral oil: $$pe_3(t) = p_7(t) \tag{27}$$

All domestic energy carrier prices are absolute prices measured in local currency per physical unit. The measured parameters reflect the historically given taxes as well. For forecasts tax rates can be changed or emission trading systems introduced.

3.5 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 distinguish the demand for 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 are given in physical terms from the energy models. Since the energy models are calculating the determinants of production in detail 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 establish 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.

It is known that agriculture is the extracting sector for biomass. Hence, 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 the extraction of biomass. Since production is again depending on domestic demand and exports, we automatically have the right dependency of extraction on exports.

For countries without input-output models we do not have the information about agricultural production, but the export figures for agriculture are extracted 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 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. We therefore 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”. Those countries with input-output models are representing about 90% of the world’s 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 are assuming 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 driver is 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.

Within WP 5 of the petrE project, the material input models will be updated and enhanced to additional categories of material extraction.

4 Evaluation of the Model

4.1 The General Architecture

GINFORS is a multicountry/multisector economic-environmental model with global coverage. The combination of these attributes is necessary for an adequate answering of global environmental questions. The explicit modelling of countries is useful, since policies are always related to specific countries with their structural properties. The sector approach is unavoidable since the relations between the environment and the economy are sector specific with different sector focuses depending on the questions to be answered. Global coverage is not only necessary in the environmental dimension, but also in the economic dimension. This becomes clear when analyzing the global impact of policies. But in country studies the international feed back effects have to be considered as well. A full picture of the economic effects of environmental policies can only be given, if the international competitiveness of the economy has been taken into consideration. Also the impact on the environment is not completely discussed without global coverage: Industries may change their location, causing leakage effects.

The literature provides two other approaches of global multicountry/multisector economic environmental modelling: The neoclassical CGE models of the GTAP family (Hertel 1997) – to which the economic-environmental-energy model GEME3 (Capros et al. 1997) belongs. 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 while minimizing global factor costs. This optimizing solution can be characterized as Ricardian, because comparative advantages determine the results. In global economic-environmental modelling GINFORS is a macroeconometric model, that can be characterized as a evolutionary model based on bounded rationality of the agents and imperfect markets. The global coverage of GINFORS exceeds that of the two other models and shall be discussed in detail below.

The first column of Table 1 gives the countries of the world in the order of the magnitude of their GDP in US Dollars for the year 2004 in absolute terms, in percent of the world total and the aggregated sums of the percentages. In column 2 for these countries the same is given for the CO_2 emissions in the year 2003. The yellow coloured countries belong in the model to the regions OPEC and ROW (Rest of the World), all other countries are explicitly part of the system. There are further explicitly mentioned countries in the model – as the smaller new member States of the EU – that are not on the list because they are too small in terms of GDP. The region ROW of course guarantees that the system is globally closed. But the important fact is that the explicitly modelled countries cover more than 95% of the world's GDP, of global CO_2 emissions, and of German trade.

All 50 countries and the two regions are linked by sectoral disaggregated (26 goods) bilateral trade and are equipped with energy models. The economies of the blue coloured countries are depicted by macro models and input-output models in sector detail. These countries cover nearly 80% of the world's GDP and 65% of the world's CO_2 emissions. Since the OECD has already produced input-output tables for additional countries, it will be possible to have some more input-output models in the system for important countries like India and Brazil. The economies of the other countries are depicted only by macro models. Only the GDP of the region ROW (Rest of the world), which covers about 2-3% of world GDP, is exogenous. Energy demand and CO_2 emissions are globally endogenous.

4.2 Parameterization

Concerning the method of parameterization, economic-environmental models can be divided into two classes: Computable general equilibrium models (CGE) and econometric models. CGE models are based on neoclassical economic theory, which implies the assumption of perfect information of the agents acting on perfect markets. Assuming for every institution a representative rational agent, the economic behaviour of that institution is the result of optimizing the objective function. In the case of households consumer behaviour is derived from utility maximization under the budget constraint, in the case of firms profits are maximized under the constraint of the production function. If the optimization period, the market structure, the type of the utility function and the technology are given, there are no degrees of freedom for the specification of the equations. From that point of view parameterization is of limited relevance, and the authors of CGE models consequently avoid econometric estimations of parameters and take important parameters like elasticities of substitution from the literature and calibrate the rest of the parameters with the information of one data point.

Table 1: Global Coverage of GINFORS

		GNI 2004 (Atlas method, World bank)			CO2 emissions 2003 (IEA) without int. bunkers/int. aviation			German Trade of Goods 2005 (Destatis) Imports			Exports		
		billions of US $	%	sum	million tonnes	%	sum	Bill. €	%	sum	Bill. €	%	sum
1	United States	12150	30,50	30,50	5728	23,70	23,70	41,3	6,6	6,60	69,3	8,8	8,81
2	Japan	4749	11,92	42,42	1201	4,97	28,67	21,4	3,4	10,02	13,3	1,7	10,51
3	Germany	2488	6,25	48,67	854	3,53	32,21	0,0	0,0	10,02	0	0,0	10,51
4	United Kingdom	2016	5,06	53,73	540	2,23	34,44	39,4	6,3	16,32	61,6	7,8	18,34
5	France	1858	4,66	58,40	389	1,61	36,05	54,6	8,7	25,05	79,8	10,2	28,49
6	China	1676	4,21	62,60	3719	15,39	51,44	39,9	6,4	31,43	21,3	2,7	31,20
7	Italy	1503	3,77	66,38	453	1,87	53,32	35,6	5,7	37,12	54,3	6,9	38,11
8	Canada	905	2,27	68,65	553	2,29	55,61	2,6	0,4	37,53	5,5	0,7	38,81
9	Spain	875	2,20	70,85	313	1,30	56,90	17,9	2,9	40,39	40,3	5,1	43,93
10	Mexico *	703	1,76	72,61	374	1,55	58,45	2,0	0,3	40,71	5,9	0,8	44,68
11	India	674	1,69	74,30	1049	4,34	62,79	3,3	0,5	41,24	4,2	0,5	45,22
12	Korea, Rep *	673	1,69	75,99	448	1,85	64,64	9,0	1,4	42,68	7,0	0,9	46,11
13	Brazil	552	1,39	77,38	302	1,25	65,89	5,7	0,9	43,59	5,4	0,7	46,79
14	Australia	541	1,36	78,74	347	1,44	67,33	1,2	0,2	43,78	5,0	0,6	47,43
15	Netherlands	515	1,29	80,03	184	0,76	68,09	53,3	8,5	52,30	47,7	6,1	53,50
16	Russian Federation *	487	1,22	81,25	1526	6,31	74,41	21,6	3,5	55,75	17,2	2,2	55,69
17	Switzerland *	356	0,89	82,15	44	0,18	74,59	23,2	3,7	59,46	29,5	3,8	59,44
18	Belgium	322	0,81	82,95	120	0,50	75,08	31,1	5,0	64,43	43,9	5,6	65,02
19	Sweden	321	0,81	83,76	53	0,22	75,30	11,3	1,8	66,24	17,2	2,2	67,21
20	Turkey *	268	0,67	84,43	202	0,84	76,14	8,2	1,3	67,55	12,8	1,6	68,84
21	Austria	262	0,66	85,09	74	0,31	76,45	25,2	4,0	71,58	42,5	5,4	74,24
22	Indonesia *	248	0,62	85,71	318	1,32	77,76	2,4	0,4	71,96	1,4	0,2	74,42
23	Saudi Arabia	242	0,61	86,32	306	1,27	79,03	1,3	0,2	72,17	4,0	0,5	74,93
24	Norway	238	0,60	86,92	35	0,14	79,17	14,9	2,4	74,55	5,7	0,7	75,66
25	Poland	232	0,58	87,50	293	1,21	80,38	16,0	2,6	77,11	21,9	2,8	78,44
26	Denmark	219	0,55	88,05	56	0,23	80,62	9,5	1,5	78,63	12,3	1,6	80,01
27	Greece	183	0,46	88,51	94	0,39	81,01	1,6	0,3	78,88	6,5	0,8	80,83
28	Hong Kong, China	183	0,46	88,97	40	0,17	81,17	1,9	0,3	79,19	4,0	0,5	81,34
29	Finland	171	0,43	89,40	72	0,30	81,47	7,4	1,2	80,37	8,2	1,0	82,38
30	South Africa	165	0,41	89,81	318	1,32	82,79	3,3	0,5	80,90	6,6	0,8	83,22
31	Thailand	158	0,40	90,21	188	0,78	83,56	2,4	0,4	81,28	2,0	0,3	83,48
32	Iran	153	0,38	90,59	348	1,44	85,00	0,4	0,1	81,35	4,4	0,6	84,04
33	Portugal *	149	0,37	90,97	58	0,24	85,24	4,0	0,6	81,99	7,4	0,9	84,98
34	Argentina *	142	0,36	91,32	123	0,51	85,75	0,9	0,1	82,13	1,0	0,1	85,11
35	Ireland *	137	0,34	91,67	41	0,17	85,92	15,4	2,5	84,59	4,8	0,6	85,72
36	Israel	118	0,30	91,96	61	0,25	86,17	1,2	0,2	84,78	2,4	0,3	86,02
37	Malaysia	117	0,29	92,26	122	0,50	86,68	3,7	0,6	85,37	3,1	0,4	86,42
38	Singapore	105	0,26	92,52	38	0,16	86,84	3,9	0,6	86,00	4,2	0,5	86,95
39	Venezuela	105	0,26	92,78	120	0,50	87,33	0,4	0,1	86,06	0,5	0,1	87,01
40	United Arab Emirates	103	0,26	93,04	96	0,40	87,73	0,3	0,0	86,11	4,3	0,5	87,56
41	Philippines	97	0,24	93,29	70	0,29	88,02	1,8	0,3	86,40	1,0	0,1	87,69
42	Czech Republic	93	0,23	93,52	117	0,48	88,50	17,6	2,8	89,21	18,8	2,4	90,08
43	Pakistan	90	0,23	93,75	103	0,43	88,93	0,5	0,1	89,29	0,9	0,1	90,19
44	Colombia	90	0,23	93,97	56	0,23	89,16	0,5	0,1	89,37	0,6	0,1	90,27
45	Egypt	90	0,23	94,20	122	0,50	89,67	0,6	0,1	89,47	1,6	0,2	90,47
46	Hungary	83	0,21	94,41	57	0,24	89,90	14,3	2,3	91,75	13,5	1,7	92,19
47	New Zealand *	82	0,21	94,61	32	0,13	90,04	0,6	0,1	91,85	0,6	0,1	92,27
48	Chile	78	0,20	94,81	53	0,22	90,25	1,3	0,2	92,06	0,9	0,1	92,38
49	Algeria	73	0,18	94,99	77	0,32	90,57	1,6	0,3	92,31	1,0	0,1	92,51
50	Peru	65	0,16	95,15	25	0,10	90,68	0,5	0,1	92,39	0,2	0,0	92,53
51	Romania	64	0,16	95,32	94	0,39	91,07	3,4	0,5	92,93	5,3	0,7	93,21
52	Bangladesh	61	0,15	95,47	33	0,14	91,20	1,1	0,2	93,11	0,2	0,0	93,23
53	Ukraine	60	0,15	95,62	296	1,22	92,43	1,0	0,2	93,27	3,6	0,5	93,69
54	Nigeria	55	0,14	95,76	50	0,21	92,63	0,7	0,1	93,38	0,7	0,1	93,78
55	Kuwait	55	0,14	95,90	58	0,24	92,87	0,0	0,0	93,39	1,2	0,2	93,93
..	..	..	..	..	..	..	..						
59	Slovak Republic *	35	0,09	95,98	39	0,16	93,04	2,5	0,4	93,79	2,9	0,4	94,30
60	Kazakhstan	34	0,09	96,07	152	0,63	93,66	2,5	0,4	94,18	1,0	0,1	94,43
..	..	..	..	..	..	..	..						
73	Bulgaria	21	0,05	96,12	46	0,19	93,85	1,0	0,2	94,34	1,8	0,2	94,66
	Cinese Taipei (Taiwan)	n.a.			245	1,01	94,87	5,1	0,8	95,16	4,2	0,5	95,19
	Rest of EU-25				174	0,72	95,59	4,1	0,7	95,82	7,2	0,9	96,11
	Rest of OPEC				322	1,33	96,92						
	World	39833	100	100	24165	100	100	625,6	100,0		786,2	100,0	
	IO model, M+E, BT (without C. Taipei)	32626	81,91		16848	69,72		465,1	74,3		598,2	76,1	
	National M+E, BT	4945	12,41		4630	19,16		119,7	19,1		128,6	16,4	
	OPEC M+E, BT	786	1,97		1327	5,49		4,72	0,8		16,1	2,0	
	Rest of World M+E, BT	1476	3,71		1360	5,63		36	5,8		43	5,5	
	Sum		100,00			100,00							

BT Bilateral trade model
M+E Macro and energy model
* Input-Output data from OECD announced or preliminary version available

The strength of this modelling approach is the clear theoretical structure; its weakness is the insufficient empirical validation and the closeness of the theoretical approach.

GINFORS is based on an evolutionary philosophy. Agents acting on imperfect markets have imperfect information, which allows only bounded rationality. Further agents are heterogeneous. From that point of view it is not possible to derive a system of factor demand functions from a production function or a system of consumption functions from a utility function. Alternative hypotheses about the agent's behavior have to be tested. The identification of the true structure will be easier than in typical macroeconomic estimations, since most of the work is done on the disaggregated level, where we have more a priori information.

The method of econometric estimation is OLS. More adequate estimators could not be used for two reasons: In many countries the length of the time series is relatively short. Further the automatic estimation for example of the price elasticities of the 70304 trade shares needs a robust and simple technique of estimation.

4.3 The Model Structure in Detail

4.3.1 The Trade Model

The structure of the bilateral trade model of GINFORS refers to Armington (1969) and is similar to that of the GTAP model. The imports of good *i* in country *k* in equation (1) are explained as part of the factor demand system of the input-output model. There we assume the same separability conditions as those in the second stage of the nested production function of the GTAP model. The exports of good *i* from country *l* to country *k* in equation (1) are nothing else than the imports of country *k* from country *l* in the third stage of the nested CES production function of the GTAP model (Hertel and Tsigas, 1997, p. 39). Equation (3) gives the function that explains the trade shares by the relation between the price of the exporting country and the aggregated import price for good *i* in country *k*. This function is specified in double logs. In the GTAP case of separable CES production functions the same specification results.

It is further assumed in the GTAP model that for all delivering countries of good *i* to country *k* the elasticities are identical. In this point we are less restrictive assuming that all price elasticities of the trade shares are different. For every element of the share matrix the price elasticities have been estimated econometrically. Since the trade matrices for each of the 26 goods have the dimension 52x52 countries or regions 70304 functions had to be estimated.

The Armington approach, which is the basis of the bilateral trade model, has been criticized very much. Hertel and Tsigas (1997, p. 41) cite the literature and argue that for global models more flexible specifications are too complicated. We agree concerning the separability conditions of the technology, which imply the two-stage approach, but with the estimation of all price elasticities at least product differentiation between the delivering countries can be achieved for the GINFORS model.

The trade model of GINFORS has the same structure as that of the INFORUM International System (Almon 1991, Ma 1997), which is a system of linked econometric input-output models. The INFORUM trade model has more product groups (120) and fewer countries (15). An advantage of the specification of the INFORUM trade model is that it tries to catch the influence of quality of the products on the trade shares. This is done taking the relation of the capital stocks of the sector in the exporting country and its rival in the importing country as a proxy for a quality index. Sectoral capital stocks are not available in international data sets, which are the basis of the GINFORS model. The INFORUM system uses richer national data.

4.3.2 Input-Output Models

As already shown, private consumption is divided into energy demand (product group 7, coke and refined petroleum plus product group 25, electricity and gas) and all other goods. The energy demand of private households is driven by energy demand for residential, which is explained in the energy models. The implicit assumption is that the energy demand of private households induced by traffic follows the same path as that of residential. There is no chance of solving this problem because the energy balances do not distinguish the demand of private households. But it is clear that residential is the major part of energy consumption of private households. The demand for non-energy products is calculated by subtracting energy demand from total private consumption. Hence, a rise in energy demand will reduce consumption of the other products.

Consumption of non-energy goods has a constant structure. This can be accepted for energy simulations, because a change in the level of non-energy demand is important, but possible changes in the structure of non-energy products are not of interest.

For the analysis of material policies it might be useful to have a price dependent endogenous structure of non-energy consumption. As already mentioned, the OECD provides the required data for consumption purposes, but there is no bridge matrix, which could link it to the product groups. A solution of the problem could be to take a bridge matrix of a representative country from national data and estimate the country bridge matrices on this basis using the known vectors of the sums of columns and rows in a RAS procedure.

The constant structure of government consumption is not problematic. For investment the constant goods structure is not a general problem, but it would be useful to have at least investment in construction and investment in equipment as independent endogenous variables. The OECD data would allow this. The further goods structures of both variables could be constant without loss of information.

The input coefficients for energy are endogenous and explained by the energy model as already stated above. Also all coefficients that are important for material inputs are endogenous. Here we assume that price dependency is given and we take the elasticities of the German model PANTA RHEI for all countries. This is the only case where we parameterize in a way that is typical for CGE modelling. That all other coefficients of are exogenous is not avoidable, because there will never be for a sufficient number of countries consistent time series of input-output tables in international data sets that are needed to do the econometric estimations. Technological change in the field of non-energy inputs has to be part of scenario formulation.

The use of the neoclassical duality to derive market clearing competitive price functions is not useful in a world of bounded rationality. Alternative specifications for price functions are the Leontief price model, which is the typical approach of the INFORUM models (Almon 1991), or the mark up hypothesis, which is often used in macroeconomic modelling.

The Leontief price model uses the input-output identities to calculate for a given vector of value added per unit of output the consistent vector of prices for gross production. In an extended model with endogenous labour demand this means that profits per unit of output have to be specified. Severe problems arise (Meyer 1997, pp. 103): Since the input-output identities are taken to calculate the price vector for given profits, it is not possible to define profits as residuals. In other words: The price vector has already been calculated as the residual in the accounting system. In some sense we are facing equilibrium prices. How can the profits be determined? They have to be interpreted as planned or expected profits, for which only rather obscure explanations can be found.

A more realistic way of price modelling is the mark-up hypothesis, which assumes that entrepreneurs calculate a mark-up on unit costs. The mark-up factor can be estimated econometrically and might depend on other variables like the prices of competing imports (Meyer et al. 1999, pp. 19). In this approach the input output accounting identities can be used – as it is in reality – to calculate the profits as residual.

The specification of the sectoral labour demand functions with gross production, real wage rate and a time trend as explaining variables follows the main stream and would be the same in a neoclassical CES specification.

Sectoral gross capital formation is depending from gross production and the real rate of interest. So there is no direct influence of technological change on investment. So if for example a sector changes its structure of energy inputs this has no effects on investment. The implicit assumption is that the of course necessary investment in new machinery is accompanied by a reduction of investment in the older machinery of the same magnitude. We choose this conservative assumption since the identification of such effects is very difficult, because the data does not allow a direct observation of sectoral investment for different technologies.

4.3.3 Energy Models

The definitional frame of the energy models is given with the energy balances of the IEA. The models calculate final demand in a deep sector structure. The structure of energy demand by carriers is depicted for the aggregates industry, services and residential and especially for electricity production and steel production.

Final demand has a deep sector structure, which allows a linkage to gross production of the sectors of the input-output models. This is an important feature, since the different abilities of the industries to realize rising energy productivity and the different importance of the industries in the countries can be mentioned in calculating energy demand. The specification of final energy demand functions with gross production of the sector in question and the energy price of the sector (weighted average of the different carrier prices) in relation to the output price of the sector is corresponding to the neoclassical approach based on a CES technology.

The energy mix is endogenous for manufacturing, services, residential and for electricity generation and steel production depending on relative prices and trends. For transport the energy mix is exogenous. For this sector carrier substitution is of minor interest or mainly policy driven in the case of biofuels.

The exports for the different carriers are given by carrier specific trade matrices. There is no alternative to this consistent way of modelling. The trade shares are exogenously given. Endogenization may be difficult, because political decisions play a role, but also not available variables like freight rates and others. As part of scenario formulations changes the impact of changes in the export structure of oil, gas and coal producing countries can be simulated consistently.

The model does not include information about reserves of fossil fuels and other determinants of energy supply. Therefore, 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. The alternative of modelling the supply side and estimating market clearing fossil carrier's prices is thinkable, but at the moment a reliable data set, which would allow this alternative modelling approach, is not given.

4.3.4 Material Models

As already described, the material inputs of gas, oil and coal in tons can be derived directly from the figures of the energy model, which are measured in oil equivalents. Since this is also a physical measure, the transformation in tons can be done without problems.

For the other material inputs, biomass, metal ores and non-metallic minerals we are missing prices to estimate price dependent input functions. The general procedure for countries without input-output models is therefore to link these inputs to GDP and to assume productivity gains. If there is an input-output model, a relation to the extracting sector is taken. In this case there might be a problem for scenario formulation: Productivity gains are happening somewhere in the structure of production. For non metallic minerals for example this may be the case with the inputs that are delivered from the sector "Other non-metallic mineral products" to "Construction", and there may be different input coefficients in the chain of value added that come into consideration. In other words: With material inputs linked to the production of material extracting sectors, material productivity is a special aspect of changing input coefficients. Insofar it is clear that without time series of input-output tables there is no alternative in the modelling approach.

4.3.5 Macro Models

The theoretical position on which the macro models are based is that of the neoclassical/Keynesian synthesis. The 5 modules balance of payments, final demand, SNA, monetary market and labour market can be aggregated to a reduced form, in which final demand is price dependent (and of course from other variables) and firms are setting prices due to unit costs, which are depending on labour, material and capital costs.

Global macroeconomic closure is given in the following way: Investment functions and savings are independent in the countries. Gaps between investment and savings in a country are closed by the balance of the current account. Since globally exports equal imports and transfers paid equal transfers received, it is guaranteed that globally investment equals savings. For the region ROW (Rest of world) it is assumed that the balance of trade is zero, which means that imports are following the exports of ROW, which are endogenously determined in the trade model. For the other transactions of the current account – international transfers – world totals are zero, so that the balances of ROW equal with opposite sign the totals of the balances of the 50 countries and the region OPEC, which are explicitly part of the system. Further the difference between savings and investment of ROW equals the sum of the balances of transfers of the 50 countries. This kind of global closure is a Keynesian feature. A rise in investment in a country will push income of that country, induce imports and in this way income in other countries. The system will find a global equilibrium with higher investment and higher savings (Meyer et al. 2007). The GTAP system gives the neoclassical alternative: Savings are globally aggregated and determine global investment, which is then distributed into regional investment by alternative rules (Hertel and Tsigas 1997, p. 54). In this case the rise of investment in one country would imply the reduction of investment in other countries.

GINFORS assumes that the overall balance is zero for all countries, which means that there are no interventions of the central banks with the implication of flexible exchange rates and the equality of the balance of the current account and the balance of the capital account with opposite sign. The endogenous exchange rates and the endogenous balance of the current account have implications for the determinants of the capital account. Since the model is used for long run simulations it seems to be plausible to assume that relative prices are the determinants of the nominal exchange rates. If the elasticities equal 1, the real exchange rates are constant, which is assumed by the purchasing power parity theory. There is much evidence that in the long run the relative prices of the countries are the most important determinants of the exchange rates (Dieckheuer 2001, pp. 205). Monetary movements influence the exchange rates in the short run and in the medium term. Of course, the distinction between tradables and non-tradables makes sense (Chinn 2006 pp. 117). But in the context of GINFORS this would only be possible for the countries with input-output models. To have a comparable measure for all countries, the GDP deflators are taken.

There does not seem to be an alternative to this modelling approach, since an econometric estimation of the exchange rates including the short term influences of the monetary variables would destabilize the system and could give wrong estimates for the long run effects. For the analysis of long run structural change driven by environmental tax reform this is a minor shortcoming.

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