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Macroeconomic Modelling of the Global Economy-Energy-Environment Nexus

An Overview of Recent Advancements of the Dynamic Simulation Model GINFORS

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1 INTRODUCTION

The environmental accounting literature documented remarkable advancements in the development and analysis of Multi Region Input Output (MRIO) databases over the last years. See e.g. Tukker and Dietzenbacher (2013) for most recent references in this regard or the prominent reviews of Wiedmann (2009) and Wiedmann et al. (2007).

However, until now this literature predominantly featured static analyses whose empirical findings remained restricted to historical reporting periods. Referring to Wiedmann et al. (2011) and the related findings of the EIPOT project,[1] we essentially presume two interacting causes in charge of this situation: First of all, dynamic simulation studies embody a huge amount of mutually interdependent processes which cannot be descriptively outlined by a couple of clearly arranged algebraic expressions. Thus, compared to elegant mathematical representations of static frameworks, dynamic models are usually exposed to a lack of transparency critique. Secondly, with regards to empirical calibration and verification issues, previous modelling attempts were hampered by an apparent lack of consistently harmonised historical time series databases with global coverage.

But when the GWS (Gesellschaft für Wirtschaftliche Strukturforschung mbH) started its latest revision of its GINFORS (Global INterindustry FORecasting System) model, the availability of global MRIO databases had changed tremendously.[2] See, e.g., Tukker & Diezenbacher (2013, p.2) in this regard: "For the first time in history the entire global economy is captured in databases of unprecedented detail (EXIOPOL and EORA) and/or with time series in both current and previous year's prices (WIOD)."

The actual model version (labeled $GINFORS_3$ within this text) therefore represents our first GINFORS release which has been built upon a fully harmonized annual set of national Supply and Use Tables (SUT), i.e., the outcomes of the WIOD project (see Dietzenbacher et al. (2013) for details). GINFORS is a dynamic simulation model which facilitates ex ante analyses of the environmental impacts embodied in international trade. Most of its recent applications accrued from the resource efficiency literature (see, e.g., Giljum et al. (2008), Lutz (2010), Lutz (2011) or Meyer (2012) in this regard). Further notable modelling exercises refer to the energy economics literature (see, e.g., Lutz and Meyer (2009) or Lutz et al. (2012). A notable model feature is given by the fact that GINFORS contains most of the essential components of an impact assessment model for analysing sustainable

[1] Online access to selected reports of the EIPOT project is available via http://www.sei.se/eipot/resources/.

[2] All modelling works discussed within this paper have been carried with support from the European Union's Seventh Framework Programme for Research (FP7). We gratefully acknowledge this financial support which originated from applications of the GINFORS model within the following FP7 projects: POLFREE (http://www.polfree.eu/), CECILIA2050 (http://cecilia2050.eu/) and ToPDAd (http://www.topdad.eu/).

economic, social and environmental development within a sustainable welfare model. Basic structures of such a model have been derived by Meyer et al. (2013).

However, as our buildup of GINFORS$_3$ started only in autumn 2012, all of the just mentioned publications do refer to former model implementations. This paper is therefore intended to inform the MRIO research community about latest progress in our realignment works of the GINFORS model.

To keep our annotations in line with the usual extent of a journal article, we cannot aim at a self-contained model description. Therefore, we rather follow a pragmatic approach for this first publication of selected essential elements of the GINFORS$_3$ version: Our outlook on the general model structure focuses the modelling of the sequence of accounts and balancing items, one of the core data sets within the System of National Accounts (SNA). According to our view, SNA consistent modelling represents a crucial feature in integrated macroeconomic policy assessments. Thus, our audience will hopefully recognize our demonstration of the fully integrated sequence of accounts module and its linkages to the Input-Output (IO) module within GINFORS$_3$ as a worthwhile contribution.

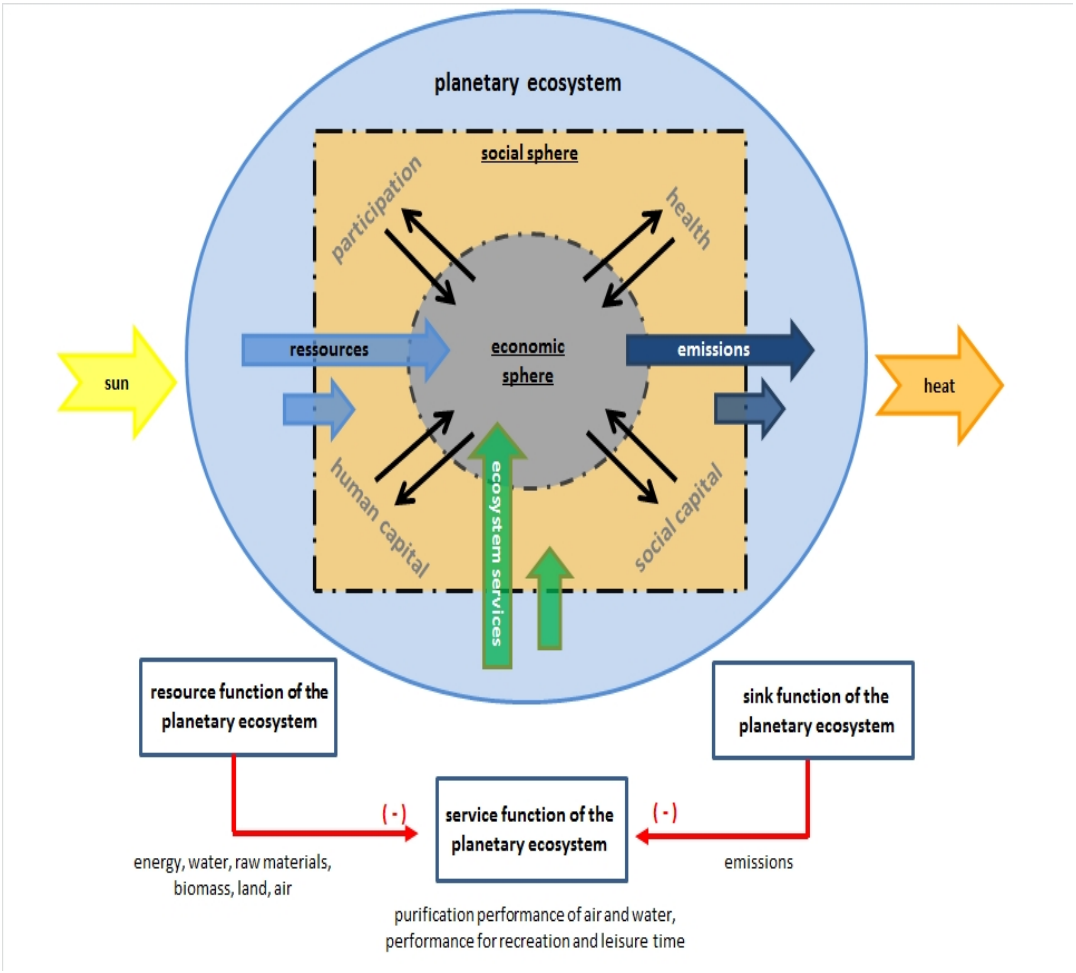
The paper proceeds as follows: Section 2 provides a general introduction to the GINFORS framework and outlines the entire data coverage of the current GINFORS$_3$ implementation. Section 3 documents our extent of SNA modelling in detail and Section 4 concludes.

2 General Characteristics of the GINFORS Model

2.1 Introductory Annotations

GINFORS contains most of the essential components of an impact assessment model for analysing sustainable economic, social and environmental development within a broader sustainable welfare model. The latter also requires a normative policy decision model as a tool for selecting and assessing the options for action in pursuing the desired goal of sustainable welfare development. Basic structures of such a model have been derived by Meyer et al. 2013. The positive impact model provides a description of the "world" with which the effects of the various options for action on the environmental, social and the economic systems can be assessed and which are important for discussing the welfare issue in globalized world. Figure 1 illustrates the basic structure of such a model with the interactions between the central values of the social sphere, such as human and social capital, and the economic sphere and shows schematically the ecosystem-founded feedback of a socio-economic subsystem on the planetary ecosystem.

Figure 1: **Basic structures of a welfare-related impact assessment model - interdependence between the economic, the social and the planetary limited ecological spheres**



Source: Meyer et al. 2013.

2.2 Methodological Annotations

From a methodological viewpoint GINFORS might be characterised as a dynamic Input-Output simulation model which is based on a comprehensive MRIO database. GINFORS evolved from the COMPASS model (see Meyer and Uno (1999) or Uno (2002) for references with regards to the COMPASS model) in the course of the MOSUS project.[1] As a global Input-Output simulation model, aims and scope of the GINFORS model are generally closely related to GTAP applications. However, whereas the later follows a

[1] The MOSUS project was funded by the Fifth Framework Programme (FP5) of the European Union. In this project GINFORS was used to simulate sustainability scenarios until 2020. See http://www.mosus.net/ for details.

standard Computable General Equilibrium (CGE) approach, GINFORS does not rely on long run equilibria of competitive markets or Say's law for a macroeconomic closure. Moreover, GINFORS assumes that agents have to make their decisions under conditions of bounded rationality on imperfect markets.

Yet, this section is not intended to echo relevant distinctive features with regards to CGE models. Interested readers are referred to Giljum et al. (2009) for a short comparison of COMPASS/GINFORS with GTAP or the related annotations of Wiedmann et al. (2007) in this regard. We would rather like to point out that the modelling of bounded rationality is not a straightforward task: Apparently, the models' reaction functions cannot be derived explicitly by applications of plain optimisation calculus. According to our view, an empirical analysis of historical developments therefore represents the natural starting point for model calibration. Economic theory provides competing behavioural hypotheses which, for each reaction function under consideration, are subject to statistical falsification tests. Accordingly, GINFORS is often also classified as an econometric model (see, e.g., Wiedmann et al. (2007)).[1]

From this follows that the availability of historical time series datasets constitutes a necessary condition for the implementation of our bounded rationality philosophy. Up to now, essential model building efforts therefore had to be devoted to the (more or less preparatory) compilation and maintenance of sufficient datasets. We do not intend to recapitulate individual challenges and possible shortcomings of this extensive and time consuming traditional practice but rather annotate that the GRAM-accounting method is basically rooted upon identical practice. Interested readers might therefore, e.g., look-up Wiebe et al. (2012) and their corresponding annotations with regards to the construction of their latest database. Apart from that, technical details of selective former GINFORS implementations were, e.g., also documented by Meyer et al. (2007) or Barker et al. (2011).

But when we started our latest revision model, this situation had changed tremendously. Hence, the empirical backbone of $GINFORS_3$ is now given by the fully harmonized annual set of national Supply and Use Tables (SUT) within its IO module as outlined by Dietzenbacher et al. (2013). This set of bottom up information has been merged with population and sequence of accounts datasets of the UN Statistics Division as well as financial data of the International Monetary Fund.

[1] This paper should not be occupied by lengthy taxonomic discussions. Thus, we will retain to this well established label. But for being precise, we like to annotate that other research disciplines would most likely prefer a distinction between econometric textbook models, and (i.a.) models of the INFORUM type as suggested by =Almon (1991)=Almon (1991). Actually, GINFORS accrued from the INFORUM philosophy which is characterized by a comprehensive mapping of variable IO coefficients by means of econometric regression techniques.

Our model therefore now enables us to simulate global developments until the year 2050, especially with regards to:

- the evolution of 35 industries in 38 national economies and a Rest of World region,
- international patterns of trade for 59 products,
- the resulting effects on main economic aggregates of national economies (e.g., public debt or disposable income of private households),
- emissions stemming from 28 energy carriers,
- and global resource demand (incl. water demand and agricultural land use).

This list already reflects that GINFORS features a high degree of endogeneity. Actually, only national population growth rates as well as world market basic prices for fossil fuels and minerals have to be determined exogenously. The computational implementation is then based on an iterative solve algorithm. However, as we rather prefer to provide our readers with an adequate representation of the contents of $GINFORS_3$, a detailed discussion of the underlying C++ environment is omitted.

2.3 The General Structure of $GINFORS_3$

From a logical perspective, four interdependently linked modules can be distinguished: The economy module, the bilateral trade module, the energy-emissions module and the resource use module. The following paragraphs provide introductory insights into the respective modelling approaches. Please note that summary information with regards to country coverage, underlying classification schemes and the full set of endogenised environmental pressure variables have also been tabulated in the appendix of this paper.

2.3.1 The economy module

For 38 national economies and a Rest of World region the economic relationships are modelled by individual **economy modules** with market clearing mechanisms. Suppliers set mark-up prices with regards to local currency denominated unit costs and demanders take these prices as one determinant of their decisions. Suppliers produce the demanded volumes. This structure ensures a balanced influence of supply and demand on the solution of the model avoiding the supply dominance of neoclassical modelling. All macro variables like GDP and its components as well as aggregate price indices or employment are calculated by explicit aggregation from the sectoral variables. In this sense the model has a bottom up structure.

As regards the **supply side,** the following modelling scheme applies for any of the 35 industries of a given national economy:[1] Input coefficients for intermediate inputs are modelled as price dependent variables. In the case of energy inputs these coefficients are driven by the inputs of related energy carriers (which are predetermined in physical units by the energy module). The capital stock is calculated from gross investment and the depreciation rate by definition. Gross investment is explained by gross production and the interest rate. Labour input in hours depends on gross production and sectorial real wage rates which are influenced by an average macroeconomic wage rate (Phillips curve approach). Compensation of employees is given by definition; the number of persons engaged can be derived from the average working time per person and the employment in hours. Unit costs are given by definition. Basic prices for sectors agriculture as well as mining and quarrying are calculated by definition from the aggregation of 8 exogenous product prices for fossil fuels, minerals and agricultural products. For all other 33 industry prices, unit costs and prices of competing import goods represent the relevant drivers. Domestic prices for 51 product groups are disaggregated from the industry prices via the make matrix. Basic prices for the 59 product groups are defined as weighted averages of import prices and domestic prices. Purchasers' prices for the 59 product groups are derived from basic prices adding tax rates and transport and trade margins. For all 35 industries value added can be calculated subtracting the sum of intermediate inputs from gross production. For 59 product groups total use is defined as the sum of intermediate and final demand. Import shares depend on the relation of import prices to basic prices. Gross output for the 59 product groups can be calculated subtracting imports from total use. The imports in local currency are converted into dollars and given to the bilateral trade model.

With regards to the **demand side,** the following impacts are explicitly captured by our modelling scheme: Intermediate demand of 59 product groups for 35 industries is implicitly given by the inputs of intermediate demand in the 35 industries. Final demand for each of the 59 product groups is sub-divided to private consumption, public consumption, gross fixed capital formation, inventory investments and exports. For each product group of private consumption real consumption per capita is explained by real disposable income per capita and relative prices. Special attention is given to private mobility in relation to mobility services, which are separated for land, water and air traffic. Energy product groups are explained in the energy module. Water demand is driven by physical water demand estimated in the resource use module. Real public consumption per capita is explained by the real sum of disposable income and net lending of the government and by relative prices of the product group. Gross fixed capital formation for 59 product groups can be calculated using the vector of gross fixed capital formation for 35 industries (see above) and a capital transformation matrix. Inventory investment is estimated by the change of gross output of the 59 product groups. Exports are given by the bilateral trade module.

[1] The Rest of World region is exhibits a slightly less complex modelling scheme.

The internally consistent bottom-up presentation of the flows of goods and services within the economy as well as the use of primary inputs within the production process inside the Input-Output system is completely embedded in the **sequence of accounts and balancing items** for the institutional sectors for 36 countries in units of local currency. Missing countries are Malta, Turkey and Rest of the World. This second major data set provides an internally consistent synthesis of all institutional sector accounts. It shows the amounts of uses and resources of each institutional sector for all transactions. Thus, policy relevant variables like disposable income of households or net lending / net borrowing of general government are pictured by this accounting module whose key features will be highlighted within section 3.

2.3.2 THE BILATERAL TRADE MODULE

The **bilateral trade module** takes for 59 product groups the export prices and the import values from the country models and converts them from local currency into dollars. For each product group, import shares of receiving countries depend on the relation between the respective export prices and an aggregated product-specific import price of the receiving country. Multiplying these trade shares with imports and summing up over importing countries gives the exports by definition. The import prices are calculated as a weighted average of export prices with the trade shares as weights.

2.3.3 THE ENERGY AND EMISSIONS MODULE

For each country the demand of 35 industries and private households for 28 energy carriers in physical terms (TJ) is explained by the **energy and emissions module**. In a first stage total energy demand of an industry is explained by gross production of the sector and the aggregated energy price in relation to the basic price of the industry. In the second stage the shares of the different carriers in total energy demand are determined by the relation of the price of the carrier in relation to the aggregated energy price of the industry. Energy demand for private households is in the first stage separated for the three purposes heating and cooling, mobility and household appliances. The energy intensity for heating and cooling is defined as the gross energy use per real capital stock of the real estate services industry. It´s evolvement is tested for dependency on relative price developments and time trends. Multiplication of the energy intensity with the real capital stock gives energy demand. Energy for mobility is explained by real disposable income of private households and the relation between the aggregated energy mobility price and the aggregated price for mobility services. Energy demand for household appliances depends from real disposable income and the relation between the household's electricity price and the price for aggregated private consumption. In the second stage in each purpose the relative prices of the energy carriers determine the structure of demand. At his point, energy demand and it´s structure have been determined for private households and all 35 industries except the electricity supply industry. Therefore, the structure of electricity and heat production has to be explained in a subsequent step. The corresponding calculations feature an explicit distinction between energy generated by renewable technologies and energy generated by nuclear energy plants. For seven renewable technologies the decision to install new capacities is modelled in dependency from investment and operating & maintenance costs, feed-in tariffs, the carbon price and market prices for electricity and

heat. Installation as well as permanent shut-down of nuclear capacities is treated as an exogenous policy variable. Given these installations, the total amount of electricity and heat that has to be produced from conventional (fossil) energy carriers can then be calculated straightforwardly with allowances for efficiency and the conversion losses. The structure of energy carriers within this are again determined by relative prices.

Energy demand in physical terms feeds back into the economic module as has been shown for intermediate and final demand. The gross energy used is transformed into CO_2-emissions for 35 industries (and private households) and 14 energy carriers assuming constant emission factors as well as constant relations between gross energy uses and emission relevant energy uses. Last but not least the module explains the emissions for 7 further air pollutants (N2O, NOx, SOx, NMVOC, NH3, CH4) in 35 industries and private households using the information from the energy use side as well as from the economy and the resource use module.

2.3.4 THE RESOURCE USE MODULE

For each country the **resource use module** explains material extractions for 12 kinds of material in tons, agricultural land use for four types in hectares and freshwater abstraction in cubic meter. The general approach for the modelling of the extraction of materials is that first an intensity in relation to an economic driver in local currency and constant prices is defined, which can be observed historically. In the forecast the multiplication of this driver with its corresponding trend dependent intensity gives the extraction in physical terms. Due to the global coverage of $GINFORS_3$ it is possible to calculate not only the domestic part of the resource use indicators but also the indirect uses due to imports of semi-finished and finished products. The general approach for the modelling of agricultural land use is that a land coefficient in hectare per ton of biomass links land use to agricultural production. For each of the 38 countries as well as the Rest of World region, freshwater abstraction is determined for the public water supply sector, the manufacturing industries and the electricity supply sector (cooling only).

3 MACROECONOMIC MODELLING OF THE $GINFORS_3$ NEXUS

Usually, many plain macroeconometric models only refer to the data set of the sequence of accounts and balancing items while conversely most of the structural macroeconomic models only fall back to the data of the IO accounts. Both approaches have undoubtedly their own right, because they are applied for answering specific questions concerning the cyclical and structural development of economy as well as impact analysis.

3.1 KEY ARGUMENTS FOR A COMPLEMENTARY SEQUENCE OF ACCOUNTS MODULE

Given our many years of experience in model-based ex ante impact analysis of medium- to long-term environmental, energy and resource-economic issues has shown that in the course of model-based policy simulations the full linkage of the two National Accounts data sets – IO accounts and sequence of accounts – provides a valuable increase in policy-relevant information. For giving an example: Policy makers should not be interested in prospective GDP and employment developments only. Rather, effects on tax revenues and

government debt should also be considered. But these can only be consistently estimated by a sequence of accounts approach.

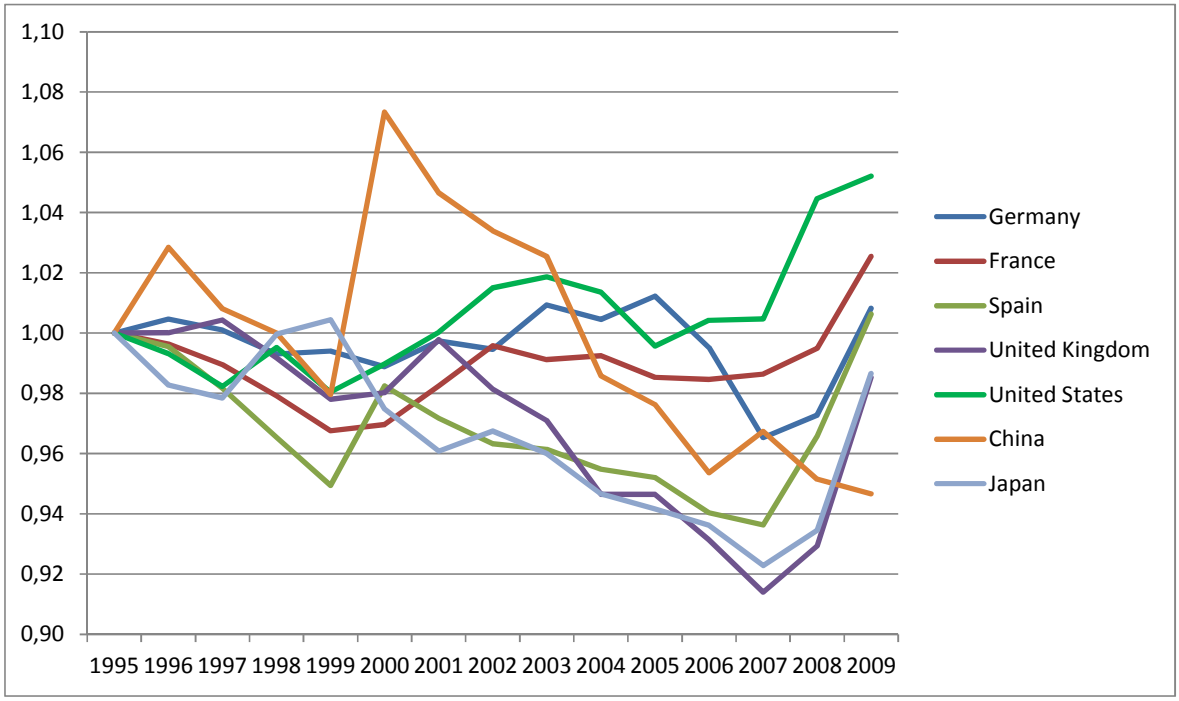
In addition to the demand for supplemental macroeconomic indicators beyond the IO accounts in the course of policy advice, there is also the desire of the macroeconomic modeller to enhance the quality of the equation system of the model and consequently the simulation results of the downstream impact analysis by endogenizing the sequence of accounts and balancing items. By doing so it is for instance possible to explain more precisely the development of consumption of private households and general government by variables which are estimated precisely within the sequence of accounts instead of falling back on variables compiled within the IO module. Hence it follows that the main advantage of such a linkage is the economically consistent estimation of disposable income and net lending/ borrowing of households, corporations and general government as well as the consistent derivation of change in general government debt. The following subsection will give a more detailed description of this aspect.

Figures 2 and 3 exemplarily illustrate the “dilemma” with regards to historical GDP and disposable income series for selected countries. They indicate the usefulness of a fully-fledged macroeconomic model which contains an IO module which is consistently complemented by the sequence of accounts and balancing items.

Figure 2 shows the differences between GDP and disposable income development of private households for selected countries in the years 1995 to 2009. Therefor the GDP in current prices as well as the disposable income of private households and NPISH are calculated as indices (1995 = 100) and the lines show the development of the ratio (disposable income index / GDP index) over the years. In most of the countries the disposable income of private households grew slower than the GDP. Only the economic crisis with the sharp reduction of GDP caused a return. While this observation holds for all quoted EU states, the figures for China and the United States show different developments. In China since the year 2000 the development of disposable income lags behind GDP, whilst in the US for many years there was a nearly similar development of GDP and disposal incomes observable.

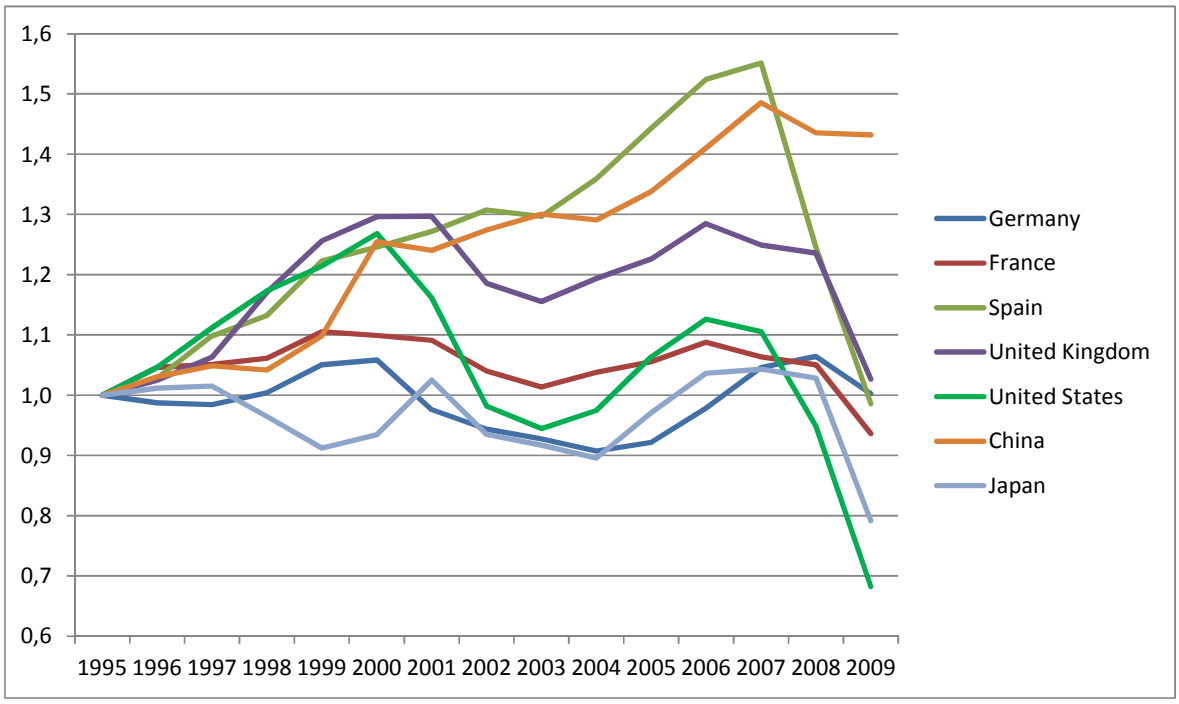
Figure 3 shows the ratio between disposable income and GDP development with regards to general government accounts of selected countries in the years 1995 to 2009. GDP in current prices as well as governments disposable income are calculated as indices (1995 = 100) and the lines show the development of the differences (disposable income index / GDP index) over the years. In many countries the disposable income of general government grew much faster than the GDP. Only the economic crisis with the sharp reduction of GDP caused a sharp slump. This is especially the case for Spain whereas the crisis affected China only slightly.

Figure 2: **Differences between GDP and disposable income development of private households for selected countries in the years 1995 to 2009.**



Source: Author' calculations

Figure 3: **Differences between GDP and disposable income development of general government for selected countries in the years 1995 to 2009.**



Source: Author' calculations

3.2 THE SEQUENCE OF ACCOUNTS MODULE

Within GINFORS the integrated sequence of accounts and balancing items consistently combines the dynamics of primary inputs (as estimated within the IO module) with final demand developments. The relevant historical data set is regularly published by the UN Statistics Division. In total four institutional sectors are distinguished (see also Figure 4): the combined sector of non-financial and financial corporations (S.11/12), general government (S.13), the combined sector of households and non-profit institutions serving households [NPISH] (S.14/15), and rest of the world (S.2).

Whereas the sector account of corporations (S.11/12) only gives a description concerning the output of goods and services, the sector account of households (S.14) also pursue the goal to describe the allocation of income to consumption and to saving. Due to the fact that the sector NPISH (S.15) is largely financed by households and also constitutes only a small sector it has been combined with the household sector. In general the "consumer" function of the household sector is of particular interest because economic growth is influenced directly by growth in household final consumption expenditure, which in turn is determined by households disposable income and by the way in which this income is divided between consumption and saving. The sector account of general government (S.13) constitutes a very important institutional sector, including central government, local authorities and social security funds. Since the government sector is responsible for production of non-market services (education, health care, government services) as well as the redistribution of income (social benefits, subsidies) all related financing costs with regard to households and corporations by taxes and social contributions and the effect on net lending / net borrowing of general government have to be completely recorded due to its direct impact on public debt.

As with all institutional sector accounts in GINFORS the following sequence of non-financial accounts and balancing items is given:

II.1.1 Generation of income account => operating surplus / mixed income

II1.2 Allocation of primary income => balance of primary incomes

II.2 Secondary distribution of income accounts => disposable income

II.4.1 Use of disposable income account => gross saving

III.1 Capital account => net lending / net borrowing

For all three institutional sectors this sequence of accounts and balancing items is completely embedded: Within each functional account all transactions related to resources (right-hand column of a T-account form) and uses (left-hand column) are set out for each variable in equation form. The final item of each account (in the uses column) is a "balancing item" to bring uses and resources into balance.

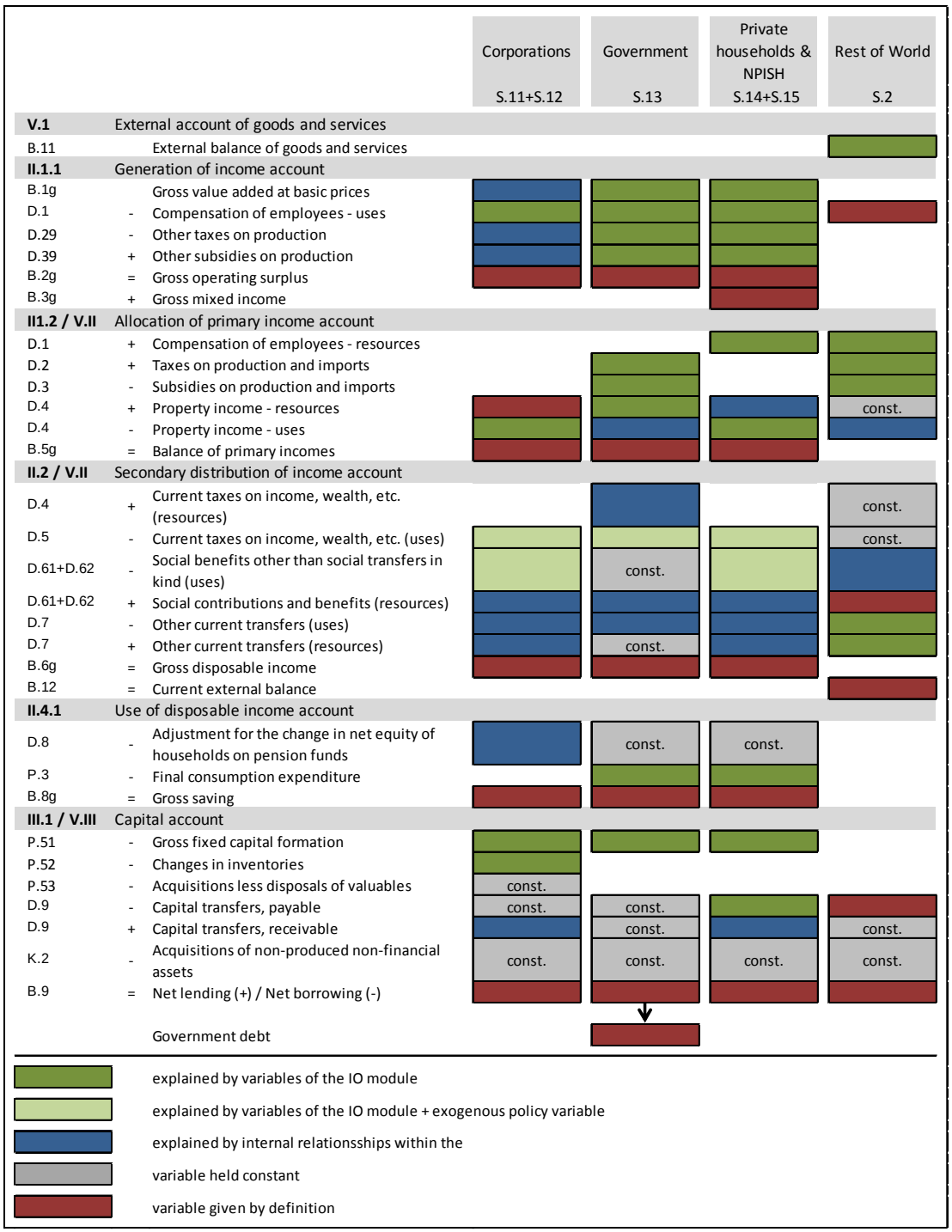
Since the rest of the world (S.2) is not really an institutional sector it comprises only that part of the accounts of the non-resident units that relates to transactions with resident units the following sequence of accounts and balancing items has been incorporated:

V.1 External account of goods and services => external balance of goods and services

V.II External account of primary income and capital transfers => current external balance

V.III Capital account => net lending / net borrowing

Figure 4: Linkages of the IO module to the integrated sequence of accounts and balancing items within GINFORS



Source: Authors' representation

Figure 4 provides a deeper insight into the modelling of the fully integrated sequence of accounts and balancing within the GINFORS model and its linkage to the IO module. For each functional account the relevant associated transactions are listed in detail with the internationally agreed transaction codes (P – transaction in products, D – distributive transactions, B – balancing items, K – other accumulation entries).

Within GINFORS the direct link to the sector accounts is given by the fact that key variables are predetermined in the IO module. These variables are highlighted in green within Figure 4 (i.a. value added, compensation of employees, taxes and subsidies on production, final consumption expenditure of households and government, gross fixed capital formation). With regard to general government (S.13) a direct link is given to the industries 31 (public administration), 32 (education), and 33 (health and social work). Income redistribution activities which are explained by the IO module and are affected by exogenously set policy variables have been highlighted in light green. These policy variables (like, e.g., rates of taxation on income, production, etc. or rates of social security contribution) can be directly modified in any simulation run.

Variables highlighted in blue are completely explained by internal relationships within the sequence of accounts whereas variables highlighted in grey are held constant because it is not expected that they should have relevance in projections and policy simulations. Variables highlighted in red are directly given by definition. This is especially the case for all balancing items.

In GINFORS this integrated sequence of accounts shows how the bottom-up calculated macroeconomic variables directly influence the generation and allocation of primary income; the amount by which this income is increased or reduced by "property income" or by various kinds of transfer (mainly taxes) or final consumption expenditures; and finally, how much is left to the institutional sector for the acquisition of tangible or financial capital. On the other hand, there is also some direct feedback into the IO module. For instance this is the case for disposable household income.

Thus Figure 4 illustrates the linkages of the IO module to the sequence of accounts within GINFORS. Obviously the key variables of the sector accounts are completely driven by the upstream compilation of these variables within the IO module in a detailed bottom-up approach.

4 Conclusions and Recommendations

Minx et al. (2009, p. 210) already concluded that "there is a general need for applying generalised IO models in scenario applications. Efforts should focus on linkages with established climate change models as well as on the scenario development within the IO context." This general need certainly still persists. However, given that several global MRIO databases have just recently been compiled at unprecedented levels of details, we feel confident to witness a surge in dynamic MRIO scenario applications over the coming years. Hopefully, formal institutional support will also allow for consecutive updates of these datasets. Otherwise, a long-lasting surge of dynamic MRIO simulation studies can hardly be expected.

Anyway, based on the just outlined modelling structure, GINFORS will provide corresponding contributions (at least) in course of the FP7 projects CECILIA2050, POLFREE and ToPDAd. Complementary modelling efforts will certainly contribute to this agenda also. In this regard, see, e.g., the EXIOMOD model which evolved from the EXIOPOL project (Tukker et al. 2013) and which will also be applied in the POLFREE project.

GINFORS exhibits a fully integrated sequence of accounts and balancing items which consistently combines the IO dynamics of primary and intermediate inputs with final demand developments. Thus, compared to static IO analyses or plain macroeconometric forecasts in terms of (S)VAR approaches, each GINFORS simulation generates a noteworthy comprehensive set of national economic indicators. In this regard, our model represents a valuable instrument for the evaluation of (sometimes conflicting) benefits and costs of far-reaching policy initiatives. For instance, main targets of the EU's sustainable growth strategy Europe 2020 (namely: employment, R&D, climate change and energy sustainability, education and the fight against poverty) can be addressed on Member States levels. In addition to these monetary indicators, the integrated modelling of environmental pressure variables also reports about relevant developments with regards to global sustainability issues. See, e.g., the EU's Sustainable Development Indicators in this regard: Next to economic measures like growth rate of real GDP per capita, resource productivity and employment rates, GINFORS routinely provides insights into global development trends until 2050 with regards to emissions, the share of renewable energy in gross final energy consumption, primary energy consumption as well as energy consumption of transport relative to GDP.

Finally, we like to annotate that GWS had not been participating in the WIOD consortium. Our extensive use of WIOD figures might therefore also be regarded as an in-depth test of compilation procedures applied and developed by the WIOD team. Our corresponding experience might be helpful for an improvement of some of these procedures. But this task remains for future research.

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APPENDIX

Table 1: Country Coverage of GINFORS_3

Running number	Country or Region	Running number	Country or Region
1	Austria	21	Hungary
2	Belgium	22	Latvia
3	Cyprus	23	Lithuania
4	Estonia	24	Poland
5	Finland	25	Romania
6	France	26	Sweden
7	Germany	27	United Kingdom
8	Greece	28	Russia
9	Ireland	29	Turkey
10	Italy	30	Brazil
11	Luxembourg	31	Canada
12	Malta	32	Mexico
13	Netherlands	33	United States
14	Portugal	34	China
15	Slovak Republic	35	India
16	Slovenia	36	Japan
17	Spain	37	Korea
18	Bulgaria	38	Australia
19	Czech Republic	39	Rest of World
20	Denmark	40	Total World

Table 2: List of Industries

Running number	NACE Code	NACE Category
1	AtB	Agriculture, Hunting, Forestry and Fishing
2	C	Mining and Quarrying
3	15t16	Food, Beverages and Tobacco
4	17t18	Textiles and Textile Products
5	19	Leather, Leather and Footwear
6	20	Wood and Products of Wood and Cork
7	21t22	Pulp, Paper, Paper , Printing and Publishing
8	23	Coke, Refined Petroleum and Nuclear Fuel
9	24	Chemicals and Chemical Products
10	25	Rubber and Plastics
11	26	Other Non-Metallic Mineral
12	27t28	Basic Metals and Fabricated Metal
13	29	Machinery, Nec
14	30t33	Electrical and Optical Equipment
15	34t35	Transport Equipment
16	36t37	Manufacturing, Nec; Recycling
17	E	Electricity, Gas and Water Supply
18	F	Construction
19	50	Sale, Mainten. and Rep. of Motor Veh. and Motorcycles; …
20	51	Wholes. Trade and Commission Trade, Exc. Motor Vehicles...
21	52	Retail Trade, Except of Motor Vehicles and Motorcycles; …
22	H	Hotels and Restaurants
23	60	Inland Transport
24	61	Water Transport
25	62	Air Transport
26	63	Other Supporting and Aux. Transp. Activ.; Travel Agencies…
27	64	Post and Telecommunications
28	J	Financial Intermediation
29	70	Real Estate Activities
30	71t74	Renting of M&Eq and Other Business Activities
31	L	Public Admin and Defence; Compulsory Social Security
32	M	Education
33	N	Health and Social Work
34	O	Other Community, Social and Personal Services
35	P	Private Households with Employed Persons

Table 3: List of Products

Running number	CPA Category	Running number	CPA Category
1	Products of agriculture, hunting and related services	31	Secondary raw materials
2	Products of forestry, logging and related services	32	Electrical energy, gas, steam and hot water
3	Fish and other fishing products; services incidental of fishing	33	Collected and purified water, distribution services of water
4	Coal and lignite; peat	34	Construction work
5	Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying	35	Trade, maintenance and repair services of motor vehicles and motorcycles; retail sale of automotive fuel
6	Uranium and thorium ores	36	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
7	Metal ores	37	Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods
8	Other mining and quarrying products	38	Hotel and restaurant services
9	Food products and beverages	39	Land transport; transport via pipeline services
10	Tobacco products	40	Water transport services
11	Textiles	41	Air transport services
12	Wearing apparel; furs	42	Supporting and auxiliary transport services; travel agency services
13	Leather and leather products	43	Post and telecommunication services
14	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials	44	Financial intermediation services, except insurance and pension funding services
15	Pulp, paper and paper products	45	Insurance and pension funding services, except compulsory social security services
16	Printed matter and recorded media	46	Services auxiliary to financial intermediation
17	Coke, refined petroleum products and nuclear fuels	47	Real estate services

Running number	CPA Category	Running number	CPA Category
18	Chemicals, chemical products and man-made fibres	48	Renting services of machinery and equipment without operator and of personal and household goods
19	Rubber and plastic products	49	Computer and related services
20	Other non-metallic mineral products	50	Research and development services
21	Basic metals	51	Other business services
22	Fabricated metal products, except machinery and equipment	52	Public administration and defence services; compulsory social security services
23	Machinery and equipment n.e.c.	53	Education services
24	Office machinery and computers	54	Health and social work services
25	Electrical machinery and apparatus n.e.c.	55	Sewage and refuse disposal services, sanitation and similar services
26	Radio, television and communi-cation equipment and apparatus	56	Membership organisation services n.e.c.
27	Medical, precision and optical instruments, watches and clocks	57	Recreational, cultural and sporting services
28	Motor vehicles, trailers and semi-trailers	58	Other services
29	Other transport equipment	59	Private households with employed persons
30	Furniture; other manufactured goods n.e.c.		

(Table 3: List of Products continued)

Table 4: List of Energy Carriers

Running number	NACE Category
1	Hard coal and derivatives
2	Lignite and derivatives
3	Coke
4	Crude oil, NGL and feedstocks
5	Diesel oil for road transport
6	Motor gasoline
7	Jet fuel (kerosene and gasoline)
8	Light Fuel oil
9	Heavy fuel oil
10	Naphta
11	Other petroleum products
12	Natural gas
13	Derived gas
14	Industrial and municipal waste
15	Biogasoline also including hydrated ethanol
16	Biodiesel
17	Other combustible renewables
18	Electricity
19	Heat
20	Electricity for e-mobility
21	Biogas
22	Hydroelectric
23	Geothermal
24	Photovoltaic
25	Solarthermal heat
26	Solarthermal electricity
27	Wind power
28	Nuclear

Table 5: List of Emissions

Running number	Formula	Identifier
1	CO_2	carbon dioxide
2	CH_4	methane
3	N_2O	nitrous oxide
4	NO_X	nitrogen oxides
5	SO_X	sulphur oxides
6	CO	carbon monoxide
7	NMVOC	non-methane volatile organic compounds
8	NH_3	ammonia

Table 6: List of Materials

Running number	Materials Type
1	Biomass Animals (Used and Unused)
2	Biomass Feed (Used and Unused)
3	Biomass Food (Used and Unused)
4	Biomass Forestry (Used and Unused)
5	Biomass Other (Used and Unused)
6	Fossil Coal (Used and Unused)
7	Fossil Gas (Used and Unused)
8	Fossil Oil (Used and Unused)
9	Fossil Other (Used and Unused)
10	Minerals Construction (Used and Unused)
11	Minerals Industrial (Used and Unused)
12	Minerals Metals (Used and Unused)