 

TNO innovation for life

EXIOPOL: A globlal, detailed Multi-Regional Environmentally Extended Input Output Table

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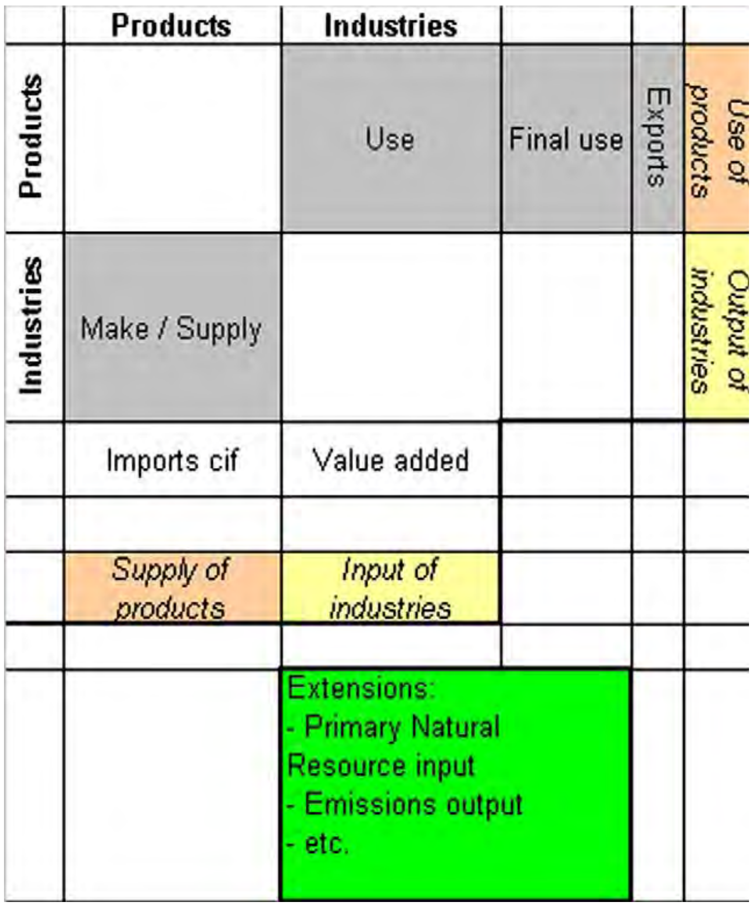
Presentation Elements

- Multi-regional EE SUT and IOT
  - What is it and what is the policy relevance ?
  - What should be improved and what are the main characteristics of ongoing projects?
  - What did EXIOPOL achieve?
  - How will it be made available?
- My own background
  - Manager at TNO, a large not for profit research institute in NL
  - Professor of Sustainable Innovation, Industrial Ecology Program, NTNU, Trondheim, Norway
  - Leader of EU funded MR EE IO projects (total: > 10 Mio Euro)
    - EXIOPOL (2007-2011) – initial detailed MR EE IO
    - CREEA (2011-2014) – update to 2007, adding physical&energy layers
    - DESIRE (2012-2016) – resource indicators & time series


EXIOPOL Partners

- TNO (NL, Not for profit research organisation)
- Wuppertal Institute (D, Resource Efficiency think tank)
- SERI (Austria, sustainability think tank with resource databse)
- NTNU (Norway, globally leading Industrial Ecology Program; involved Rensselaer Politecnic of the US, then chair of IIOA)
- IPTS (EU research institute, ‘foresight think tank’)
- Groningen University (NL, developed ‘non survey trade linking routines’)
- CML, Leiden University (NL, ‘Father of LCA’)
- GWS, (D, developers of GINFORS, a global economic model based on OECD IOT)
- ZEW (D, GEM E3 model specialists)

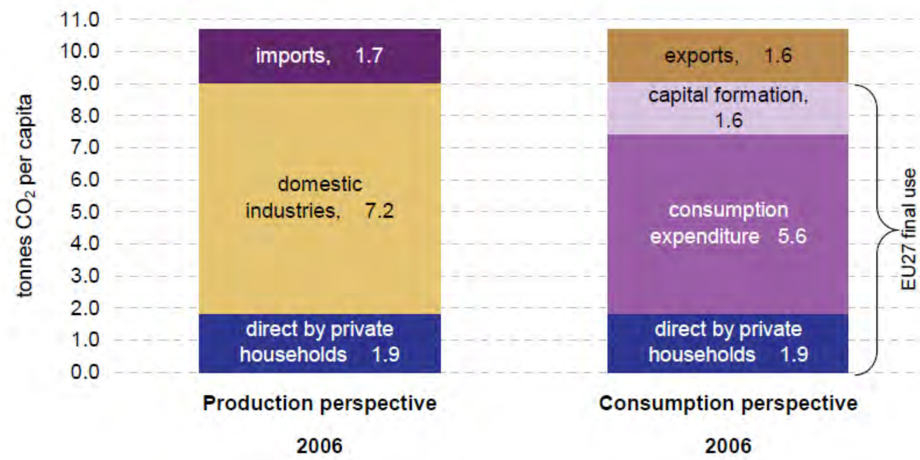

Backgrounds on SUT/IOT

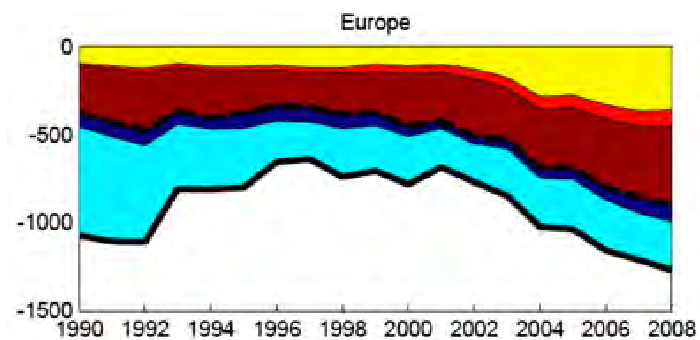


- EE SUT for a single country
  - Economic Supply and Use
  - By industry: emissions and primary resource use
- Can provide you
  - Per final use category: value added by industry
  - With impact per Euro per industry known: life cycle impacts per final use category
- Advantages
  - Inherently complete
  - Inherently consistent

Limitations of existing SUT/IOT in Europe

- Sector detail:
  - ESA95 -> 60 sectors
  - Several EU27 countries incomp
  - No split of environmentally relev sectors like agrifood, energy, m
- Extensions:
  - 8 voluntary air emissions
  - Little else
- Imports:
  - No non-EU data
  - Domestic technology assumption has shortcomings






So what you need: detailed Multi-Regional EE SUT SUT/IOT

- Ideal solution: a database that links country SUT/IOT via trade
  - Country SUT/IOT including value added and final demand (red)
  - Import and export trade matrices for intermediate and final demand (green)
  - Exensions: emissions, energy, materials (grey)
- Preferably with detail in environmentally relevant sectors..
- ..and many emissions/extensions

	Industries				$Y_{*,A}$	$Y_{*,B}$	$Y_{*,C}$	$Y_{*,D}$	q
Products	$Z_{A,A}$	$Z_{A,B}$	$Z_{A,C}$	$Z_{A,D}$	$Y_{A,A}$	$Y_{A,B}$	$Y_{A,C}$	$Y_{A,D}$	q_A
	$Z_{B,A}$	$Z_{B,B}$	$Z_{B,C}$	$Z_{B,D}$	$Y_{B,A}$	$Y_{B,B}$	$Y_{B,C}$	$Y_{B,D}$	q_D
	$Z_{C,A}$	$Z_{C,B}$	$Z_{C,C}$	$Z_{C,D}$	$Y_{C,A}$	$Y_{C,B}$	$Y_{C,C}$	$Y_{C,D}$	q_C
	$Z_{D,A}$	$Z_{D,B}$	$Z_{D,C}$	$Z_{D,D}$	$Y_{D,A}$	$Y_{D,B}$	$Y_{D,C}$	$Y_{D,D}$	q_D
W	W_A	W_B	W_C	W_D					
g	g_A	g_B	g_C	g_D					
C & L	$Capital_A$	C_B	C_C	C_D					
	$Labor_A$	L_B	L_C	L_D					
Environ Ext	$NAMEA_A$	$NAMEA_B$	$NAMEA_C$	$NAMEA_D$					
	$Agric_A$	$Agric_B$	$Agric_C$	$Agric_D$					
	$Energy_A$	$Energy_B$	$Energy_C$	$Energy_D$					
	$Metal_A$	$Metal_B$	$Metal_C$	$Metal_D$					
	$Mineral_A$	$Mineral_B$	$Mineral_C$	$Mineral_D$					
	$Land_A$	$Land_B$	$Land_C$	$Land_D$					

Key tasks

- Workstream III.1: Inception
  - WP III.1.a Scope and architecture development: WP III.1.b: Providing country generic externality data per ‘substance’:
- Workstream III.2: Gather, align and detail SUT data
  - WP III.2.a: EU27
  - WP III.3.a: 16 non EU countries and real Rest of World (rRoW)
  - WP III.2.c: Specific work on households and waste
- Workstream III.3: Gather environmental extensions
  - WP III.2.b: EU27
  - WP III.3.b: 16 non EU countries + rRoW
- Workstream III.4: Trade-links, database, link with models
  - WP III.4.a: Link SUT data via trade
  - WP III.4.b: Overall database construction
  - WP III.4.c: Interface with models

How we created EXIOBASE - Harmonized SUT

- Working with SUT as core *(// GTAP, IDE)*
  - Trade and FD is in products
  - Emissions and resource extractions are by Industry
- Production routine
  - Gather and create balanced SUT in bp in original sector format
    - EU: Eurostat SUT with S in bp, U in pp, few give valuation layers - > reverse engineer Ubp from IOT and Sbp
    - Non EU: often IOT, heroic assumption of diagonal S
  - Detail
    - Gather more totaled industry & product totals in EXIOBASE classification (FAO, IEA, Eurostat SBS, Indstat, Prodcom, etc.)
    - Create co-efficient tables estimating use and supply by industry
      - AgriSAMS for food and agriculture
      - IEA database, information on material extraction, LCA co-efficients, SUT/IOT othe countries for other estimated co-efficients
    - Use balancing routine that minimizes entropy to create detailed tables

How we created EXIOBASE - Harmonized EE

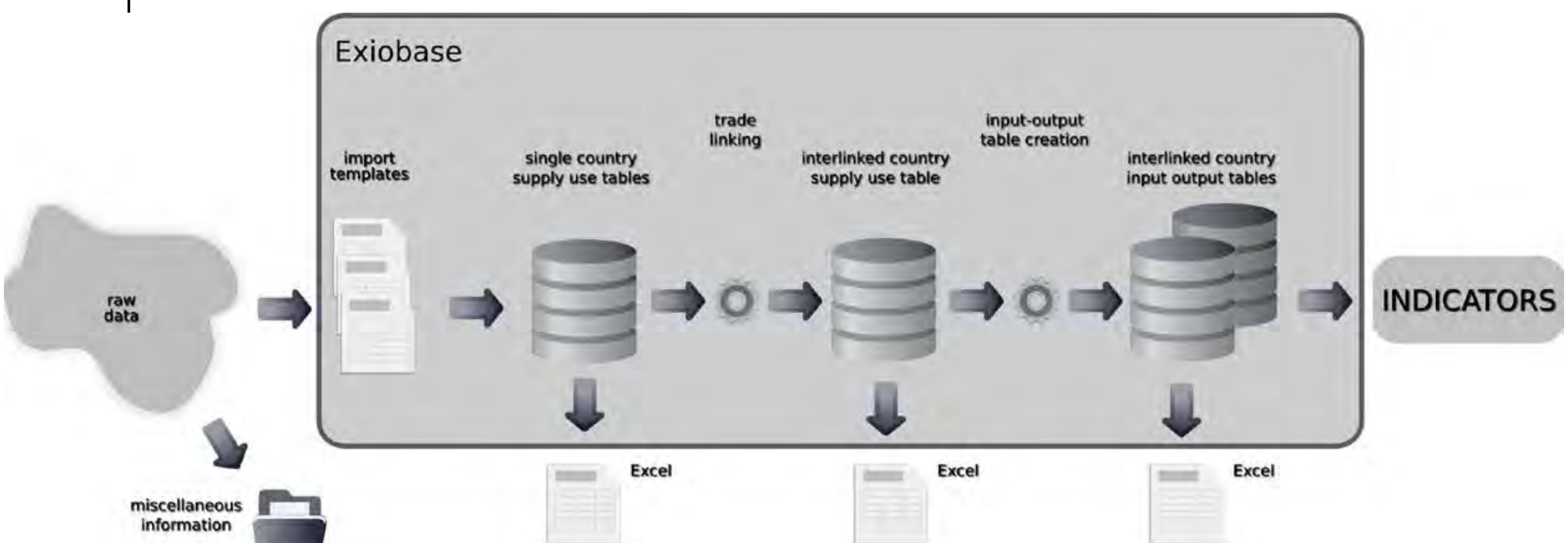
- Resources: allocation SERI (FAO, USGS, etc.) database to extracting sectors
- Emissions
  - Allocation of EIA database to sectors + emission factors (IPCC, CLRTAP, etc.)
  - Other activity variables + emission factors
- Land, Water: mainly FAOSTAT plus allocation
- Allows calculating
  - MFA indicators (known Eurostat method: adding up mass)
  - Proxy for the EF (known method: land use + transforming CO2 in land
  - LCIA indicators (known method: see e.g. CML LCIA handbook of Guinee et al with Springer)
  - Externalities (calculated per sector, country, emission varying assumptions on stack height etc.)


How we created EXIOBASE: – Trade links

- Use bp is separated in Use dom and Use imp
- Use imp is further allocated to country of origin with trade shares (harmonized UN COMTRADE by Feenstra et al.)
- When we do so for all countries, we get an ‘implicit export’ by country that in theory should match export vector in Use table
- It does not due to
  - Valuation differences (cif versus fob)
  - Statistical differences / error
- We match this by
  - Using Exports in SUT as constraint;
  - Rescaling so that total imports = total exports at global level
  - GRAS is applied to the bilateral Import Use tables to get a balanced system

The result: EXIOBASE

- The EXIOBASE database has 3 main blocks:
  - 1: Harmonized EE SUT (EU27+16 others > 95% global GDP)
    - 130 sectors & products
    - 30 emissions, 80 resources, 60 IEA energy carriers, land, water
    - Handles indicators like EF, MFA, external costs, LCIA
  - 2: Global MR EE SUT
    - Split up Use import via UN COMTRADE trade shares
    - Yields implicit exports // exports in S -> rebalancing needed..
    - ...affects tables & GDP but alternative is ‘trade with aliens’
  - 3:Global pxp and ixi MR EE IOT by collapsing MR EE SUT



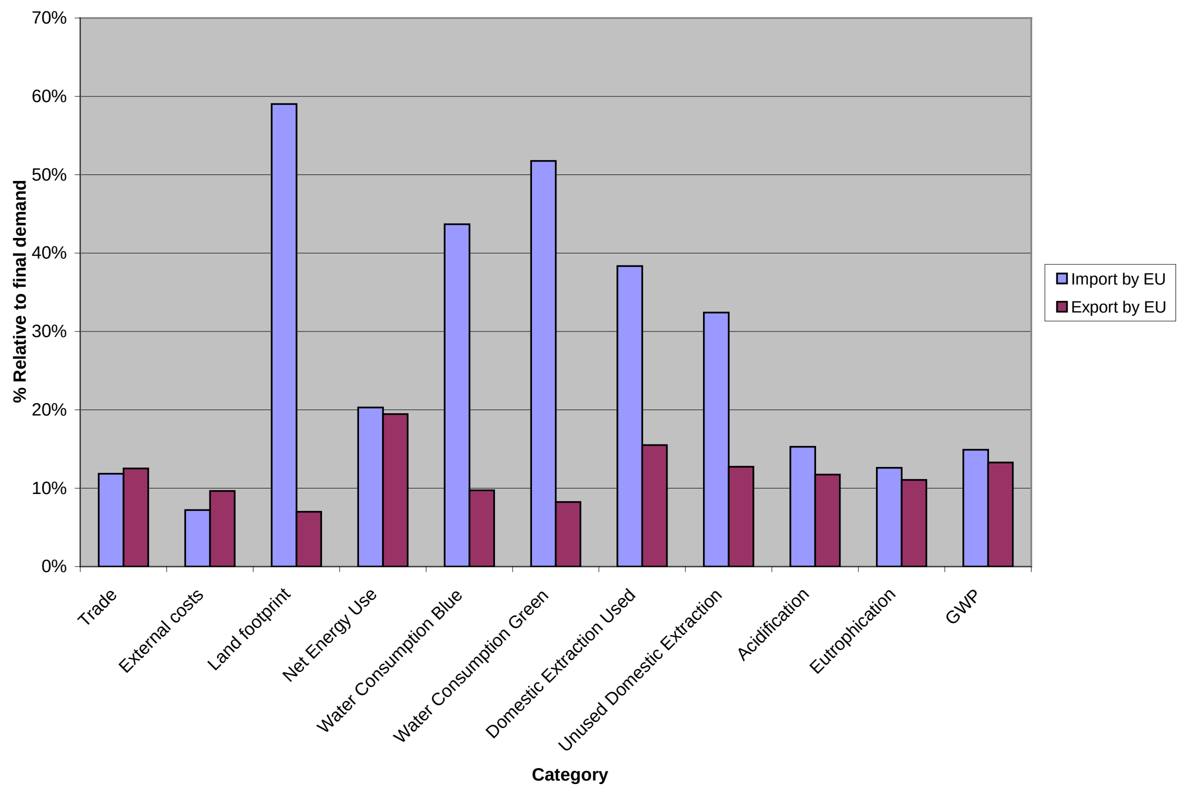
Some analyses with EXIOBASE


Some EXIOPOL results: Impacts of final consumption per capita

Impact type	Unit	Final demand /cap	Import/ cap	Export/ cap
External costs	Euro	1191	86	115
Land footprint	km2	1,7	1,0	0,1
Net Energy Use	GJ	113	23	22
Water Consumption Blue	m3	767	335	75
Water Consumption Green	m3	4446	2301	367
Material Extraction Used	Ton	17,0	6,5	2,6
Unused Material Extraction	Ton	13,8	4,5	1,8
Acidification	kg SO2 eq.	64,2	9,8	7,5
Eutrophication	kg PO4 eq.	8,2	1,0	0,9
GWP	Ton CO2 eq.	12,5	1,9	1,7

N.B. GWP includes unlike the Eurostat data non CO2 GHG

Some EXIOPOL results: embodied pollution



- Pollution embodied in EU27 imports and exports relative to pollution driven by final demand
- Europe is a net exporter of pressures except externalities

Some EXIOPOL results: External costs versus GDP

		External cost	GDP (Value added)	In %
Euro	EU	5,89E+11	8,45E+12	7,0%
	non-EU	1,76E+12	2,56E+13	6,9%
	Total	2,35E+12	3,41E+13	6,9%

- For both EU as non EU 7% of GDP!
  - For air emissions only
  - Our method does not cover well biodiversity impacts and loss of ecosystem services
- Why is EU a next exporter of externalities?
  - No external cost data for non EU countries
  - Something had to be done – PPP were used
  - Real question: how do you value external costs of wealthy economies versus poor economies?


Some EXIOPOL results: External costs

- Respiratory impacts and climate impacts dominate

Category	Unit	Region	Colored: in EU imports	Colored: in EU exports	Colored: on EU terr.	% of total
Carcinogenic effects	Euro	EU	4,75E+09	8,01E+08	5,55E+09	0,9%
		non-EU	6,43E+08	1,70E+10	1,76E+10	1,0%
Non-carcinogenic effects	Euro	EU	5,89E+07	7,54E+06	6,64E+07	0,0%
		non-EU	4,94E+06	1,80E+08	1,85E+08	0,0%
Respiratory effects (inorganic)	Euro	EU	3,67E+11	2,89E+10	3,96E+11	67,2%
		non-EU	2,14E+10	1,13E+12	1,15E+12	65,3%
Aquatic ecotoxicity	Euro	EU	2,06E+08	3,54E+07	2,42E+08	0,0%
		non-EU	3,50E+07	9,78E+08	1,01E+09	0,1%
Terrestrial ecotoxicity	Euro	EU	2,94E+10	5,98E+09	3,53E+10	6,0%
		non-EU	4,63E+09	1,22E+11	1,27E+11	7,2%
Terrestrial acidification/nutrifica	Euro	EU	2,82E+10	3,65E+09	3,19E+10	5,4%
		non-EU	2,40E+09	9,17E+10	9,41E+10	5,3%
Total Climate Change	Euro	EU	1,04E+11	1,61E+10	1,20E+11	20,4%
		non-EU	1,81E+10	4,81E+11	4,99E+11	28,4%
Total	Euro	EU	5,34E+11	5,54E+10	5,89E+11	100,0%
		non-EU	4,15E+10	1,72E+12	1,76E+12	100,0%


The future of EXIOBASE

EXIOPOL's follow-up's: FP7 CREEA and DESIRE

- Added value of EXIOPOL
  - Unique detail and large number of extensions
  - Focused on environmentally relevant sectors (agri, energy, mining, etc.)
- FP7 CREEA (Compiling and Refining Economic Environmental Accounts)
  - EXIOPOL core partners with a.o. SCB, CBS, ETH, 2-0 LCA, EFI
  - Environmental accounts for water, carbon, materials, forests
  - Willl be used to update EXIOBASE to EXIOBASE 2.0:
    - To 2007
    - Full alignment of IEA energy categories -> more products
    - Making it an MR Energy & Physical SUT
  - DESIRE (Developing a System of Indicators for Resource Efficient Europe)
    - Will add time series
    - Will add information and indicators of small 'critical material' flows and biodiversity

Future availability of EXIOBASE

- Though we have 2 follow-up projects, there is a problem
  - We cannot guarantee updates of EXIOBASE without funding
  - Without updates, EXIOBASE is dead in a few years
  - We noted there is no clear ‘host’ that can take over EXIOBASE
- We hence opted for a not for profit model
- How it will work (compare Eco-invent)
  - Joint partnership of core partners being legally elaborated
  - Making it available via a website
  - Fee in the 1500-2000 Euro range
  - Revenues only to be used for database improvements and updates
  - Aggregated and country example freeware available in this week or so
  - Full database some time after (legal issues…..)
  - www.exiobase.eu


Conclusions

- EE IO has in my view huge potential to understand the global economic, material and energy metabolism
- Projects like EXIOPOL are first steps – no doubt ‘strange’ data phenomena will be found in that database I am so proud of
- They provide however also huge potentials
  - For really using (and by this cross checking) official data
  - For analysing consistency between data sets at a country-overarching level (that NSIs usually cannot do)
  - To work from here with NSIs and Eurostat to see how simple changes in data gathering create major jumps in usability and quality
- We will make EXIOBASE available via a not-for profit model similar to Eco-Invent to create funding for updates.

THANKS FOR YOUR ATTENTION!


Calculating external cost indicators

- Method for calculating externalities in an IO framework
  - Developed by Wolf Mueller and Rainer Friedrich, IER
  - Problem was: IO is at country level, externalities use temporally and spatially specific data
- Approach in brief:
  - 20 pollutants: estimate stack hight and if emitted in rural or urban areas, then use ECOSENSE to calculate externalites
  - 20 pollutants: use LCIA (Impact 2002+) to calculate DALYs and PDFs, monetarise
  - Some specific assessments
  - Gives external costs per sector, country, substance for EU
  - Assume PPP for non EU countries

How we created EXIOBASE – SUT/IOT system

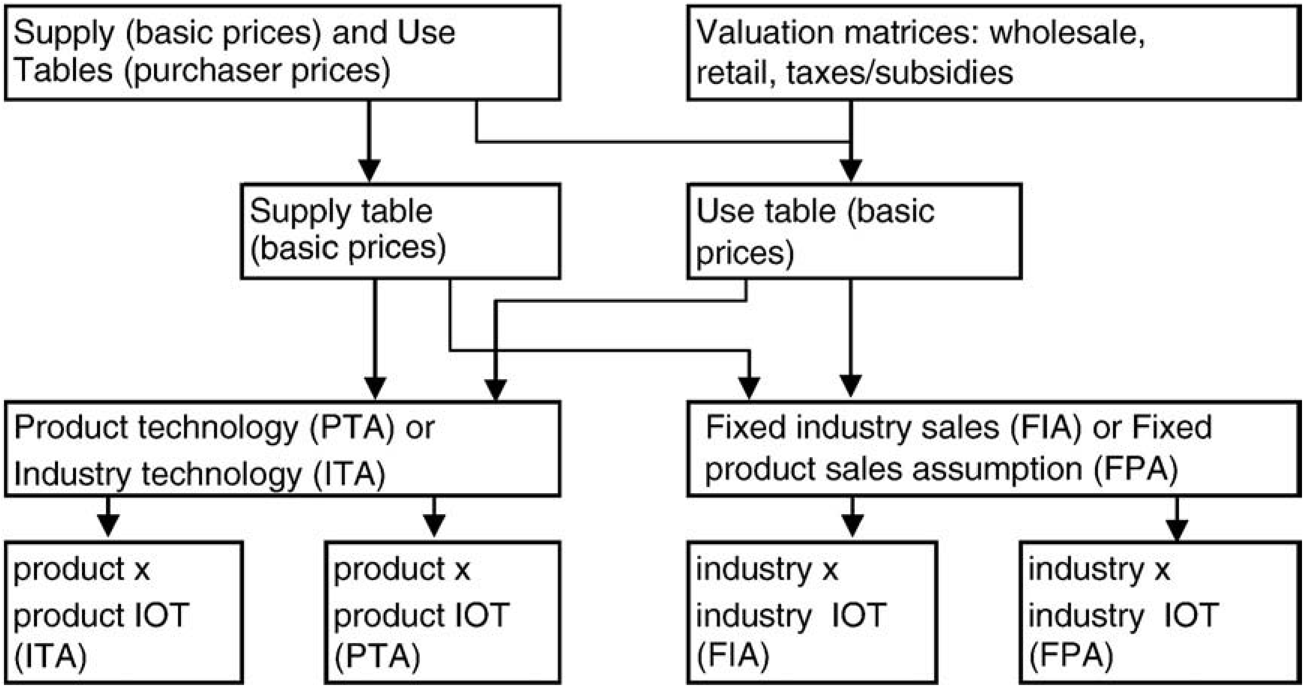


Figure courtesy of Jose Rueda Cantuche, EU DG JRC IPTS, Sevilla, Spain

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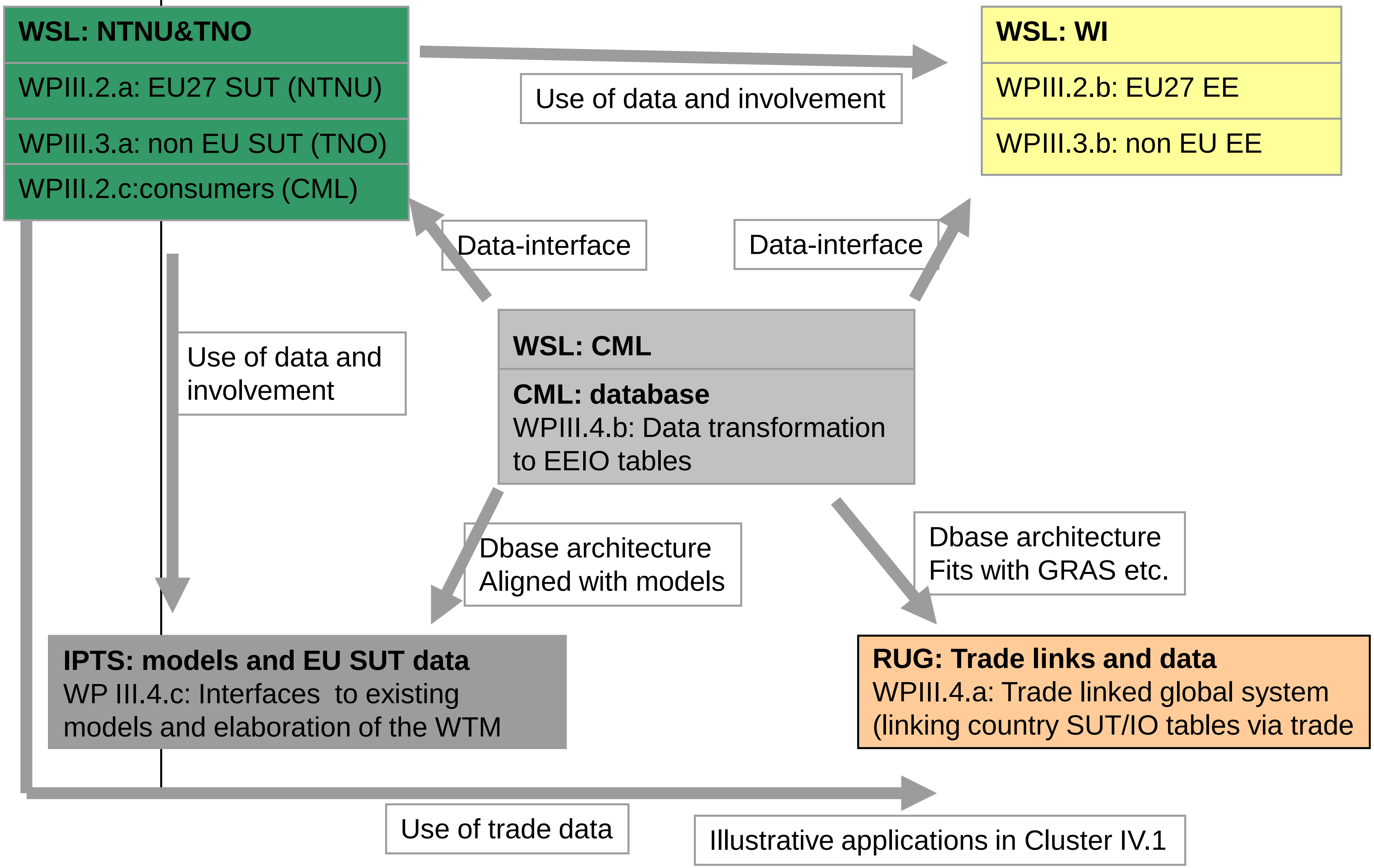
Or, in another perspective:



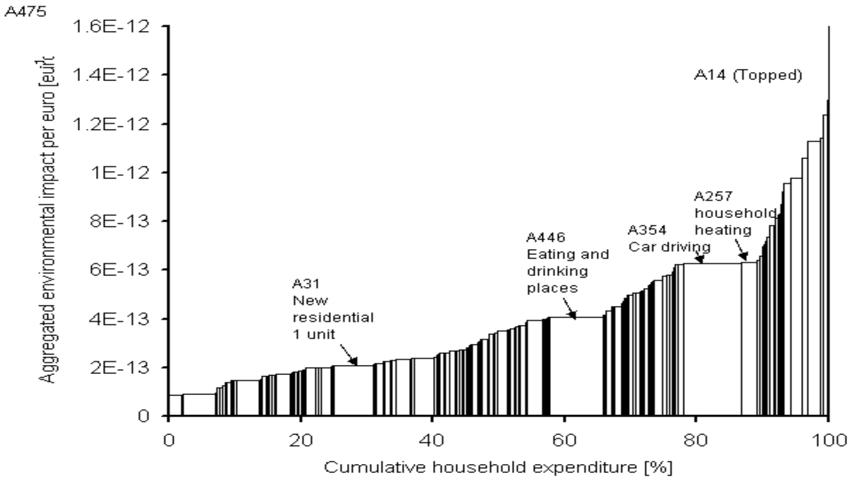

Major (research) initiatives in creating (Global) MR EE SUT/IOT

Project name	Funding	Countries	Type	Detail (ixp)	Time	Extensions	Approach
IDE JETRO (Inomata)	Japan	Asia Pacific (10)	MR IOT		2000, 2004	-	Harmonize IOT; Link via trade; move discrepancies to RoW
GTAP (Hertel)	Subscrip-tion	World (113)	MR IOT	58x58	2000, 2004	10 (GWP)	Harmonize trade; use IOT to link trade sets; relative crude IOT estimates
WIOD (Dietzenbacher, RUG)	EU FP7	World (40)	MR SUT	30x60	1995?- 2000- 2006	20+	Harmonize SUT; Link via trade; problems with discrepancies
EXIOPOL/ CREEA (Tukker, TNO & NTNU))	EU FP6/7	World (43)	MR SUT	129x129	2000, 2007	30 emissions, 60 IEA energy carriers; water, land, 80 resources	Create SUT bp; Split Use_dom and Use_imp; Detail and Harmonize SUT; Use trade shares to estimate implicit exports; confront with exports in SUT, RAS out differences, add extensions
AISHA/ EORA (Lenzen, Un. Syndney)	Austral-ian NSF	World, t.b.d. (200?)	MR SUT	t.b.d (>150?)	1990- 2006?	t.b.d.	Create initial estimate; Gather all data available; apply in original format; Formulate constraints; Detect & judge inconsistencies; Let routine calculate Global MR SUT/IOT
Eurostat (Remond-Tiedrez, Moll)	Eurostat	EU 27 aggregate	SUT	59x59	1995- 2007	10 (GWP)	Create SUT bp, Split intra and extra EU trade, aggregate to EU27 totals, remove intra EU imports / export differences to RoW, add extensions

Note: WIOD seems only project that develops current and constant price tables

What you can calculate with EE SUT and IOT

- EU EIPRO (480 sector EE IOT)
  - Priority setting of products
  - Proved that food, mobility and housing were prio's
- EU Diet change
  - Change to healthy diets by changing demand vector
  - Showed rebounds by linking EE IOT to the CAPRI model



Tukker (ed., 2006), Journal Industrial Ecology 10: 3

	Aggregated environmental impacts (%)			
	Scenario 0: Status quo	Scenario 1: Recommendations	Scenario 2: Recommendations including red meat reduction	Scenario 3: Mediterranean
Sub-scenario 'All'				
Food	27	27	25	25
Non-food	73	73	73	73
Total	100	100	98	98
Sub-scenario 'All + first order'				
Food	27	27	25	25
Non-food	73	73	74	73
Total	100	100	99	98
Sub-scenario 'All + first and second orders'	100	100	99	99

Tukker et al., 2011, Ecological Economics (in press)

Relations between SUT and IOT

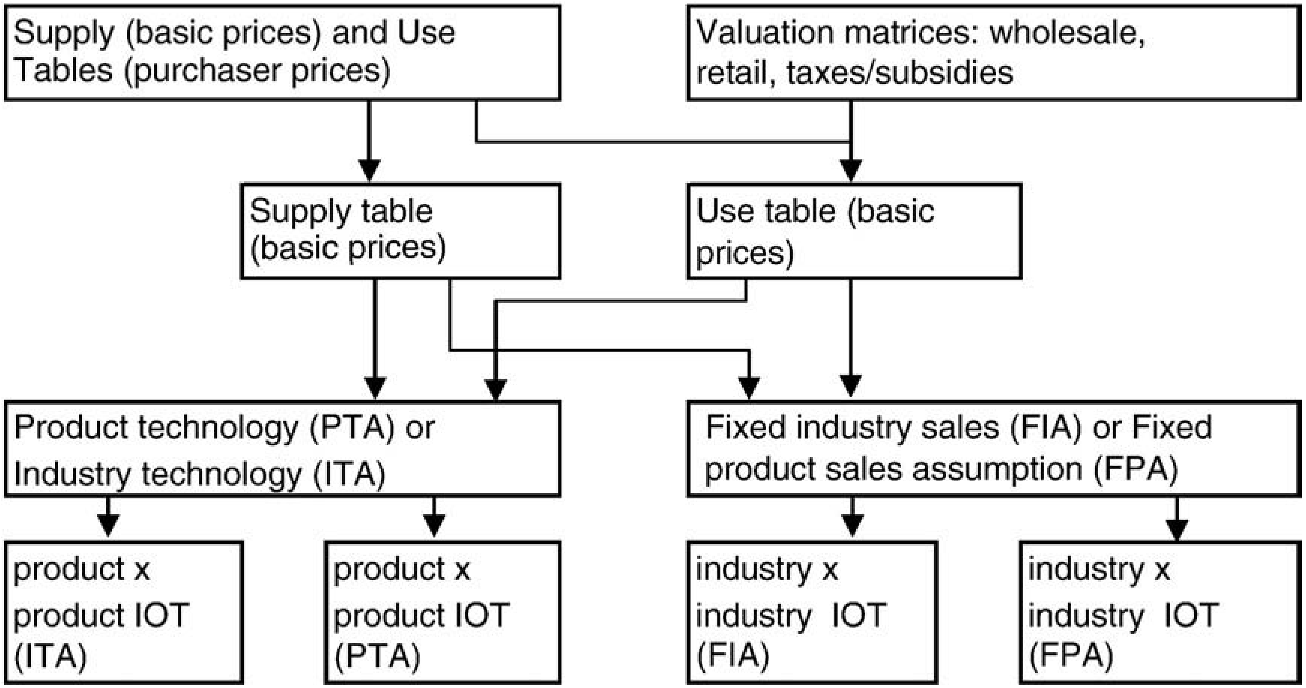


Figure courtesy of Jose Rueda Cantuche, EU DG JRC IPTS, Sevilla, Spain


How EXIOPOL did produce its data set - SUT

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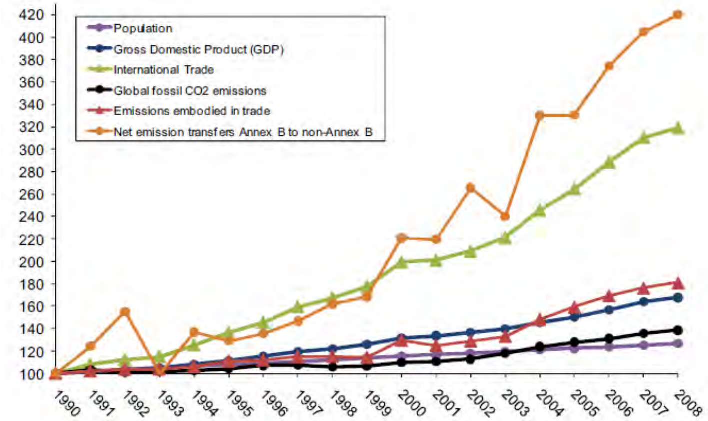
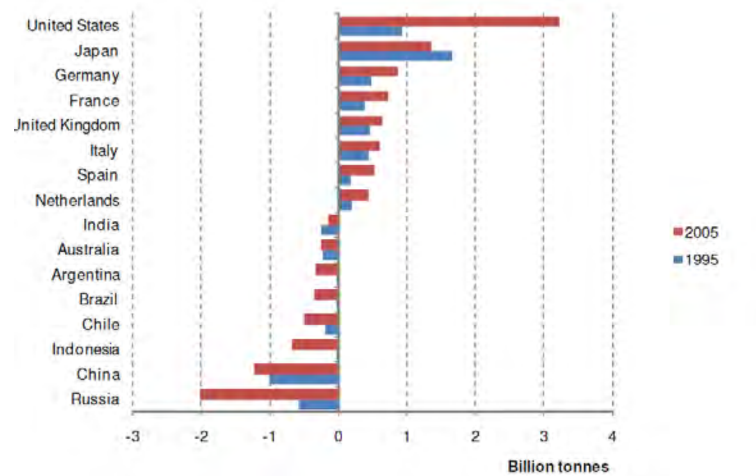
Relevance of imports - MR EE SUT and IOT

- Peters et al., PNAS 2010:
  - Global CO2 emissions (black)
  - Transfer from Annex B to non Annex B (yellow)
  - Similar work of Ahmad and Wyckoff, 2003, Davis and Caldeira, 2010
- Giljum et al. (in press)
  - Focuses on materials
  - Gives net materials imports and exports in trade





Longer term roadmap ideas for EE SUT/IOT

- Further harmonization of SUT/IOT in more detail
- Expanding number of countries covered
- Integration with physical data to P-SUT (e.g. with FAO and IEA data)
- Harmonizing trade data sets/shares (both economic as physical)
- Integration of Life cycle inventory data (is SUT/IOT by single process)
- Integration of spatially explicit information for land and water use
- Inclusion of monetary and physical capital stocks


Some issues about data availability

- Eurostat works with
  - IPTS and Konstantz on gap filling ESA95 SUT
  - TNO, RUG, NTNU, CML on creating an EE SUT
- For 16 out of 27 EU countries (75% GDP) an ‘Excellent data set’
  - 3-4 countries with valuation layers transmitted to Eurostat
  - 12 other countries that give voluntary information, but many do not want to have this published!!!!!
- Even in our Eurostat project we could not work with these tables
- We will publish
  - Aggregated EU27 table constructed by separating Uimp, non EU and Uimp, EU, rebalancing intra EU trade
  - With extensions, and several analyses
- In a way weird – WIOD, EXIOPOL are forced to redo this work with less information…..hope with time this will improve

How do I see collaboration with you?

1. There seems interest from UN SD, WB, others to work on MR IO
   - Project partners from EXIOPOL, AISHA, WIOD could help
     - Sharing e.g. EXIOBASE trade linking routine
     - Sharing experiences with data harmonization
     - Cf Eurostat's official EU27 EE SUT build by EXIOPOL&WIOD staff
2. Countries build own EE SUT/IOT but face pollution embodied in trade
   - A joint WG of NSIs and researchers could link and harmonize such initiatives, compare OECD WG on Material Flow Analysis
   - CREEA can offer some funds to support this,,,,
   - ,,,would there be interest? What would be a good host ? (e.g. UNCEAA, London Group, UNEP SETAC LCI, OECD….)
3. Support to countries with less data seems feasible too
   - EXIOPOL, AISHA had to develop many gap filling routines
   - Crude but usable EE SUT probably can be estimated with FAOSTAT, IEA and macro-economic data

Towards more formal MR EE IO tables?

- Linking country tables to a global MR SUT/IOT is not the problem
  - EXIOBASE creates this in 20 minutes from country tables and trade data
  - Has a flexible set up with regard to sector classifications
- The problem is (harmonized) data:
  - SUT & IOT (NSIs)
    - Make valuation layers available – particularly EU must have them….
    - Use harmonized sector classifications where possible – really!
  - Trade (UN, WB, OECD, NSIs)
    - Put effort in harmonization (‘mirror statistics puzzle’ in UN COMTRADE)
    - Start work on service trade sets…..
  - Physical data (energy – IEA; agro-food: FAO)
    - It helps to use CPC as product classification in FAOSTAT and IEA
    - IEA: ideally, try to move to an industry classification based on ISIC
    - …and move from territorial to resident principle