Environmentally extended multi-country input-output models: models and data structures

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Session 5: Input-output models

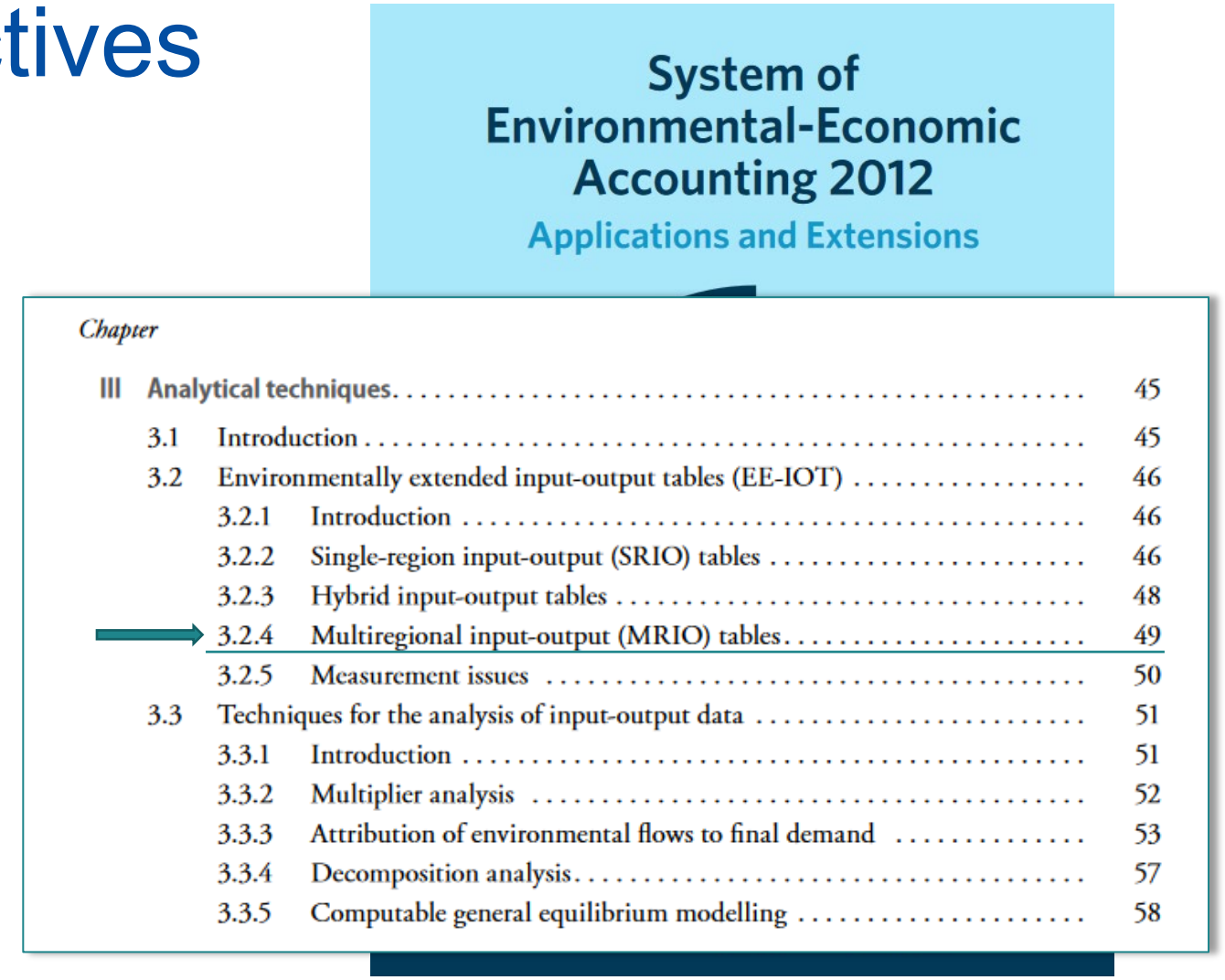
Stephan Moll, Eurostat

Background & objectives

- SEEA Applications and Extensions:

⇒ contribute to further clarify applications of environmental MRIO analyses

- Eurostat has started to produce and disseminate results from environmental MRIO modelling based on FIGARO MRIO tables



Content

- Formulation of inter-country input-output table and derived matrices and vectors
- Variants of environmentally extended Leontief-type models
- Data structure(s) for modelling results
- Implementation issues (production, dissemination, communication)

Formulation of inter-country input-output table and derived matrices and vectors

Scheme of inter-country input output table

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Indices (1)

R osource country, i.e. country hosting industry *i* that emits CO2

S country of final demand, i.e. country where final use is taking place

T country f intermediate use,

also denoting the country of final production in which final products *j* are produced (last production stage before delivered to final use)

Indices (2)

i, j industry or product, respectively, in country *R, S, T*

p type or category of final use/demand in country *S*

Indices (3)

numbering indices used:

N	number of countries, respectively *R, S, T*
n	number of production activities (industries) and their outputs (products), respectively *i, j*
k	number of final use categories *p*

Inter-country intermediate use matrix *Z*

- **Z**
- $nN \times nN$
- Z_{ij}^{RT}

Multi-country final use matrix *Y*

- **Y**
- $nN \times kN$
- y_{ip}^{RS}

Multi-country output vector *x*

- **x**
- $nN \times 1$
- x_i^R and/or x_j^T

Multi-country environmental pressure vector *b*

- **b**
- $nN \times 1$
- b_i^R

Multi-country technical coefficients matrix *A*

- $\mathbf{A}$
- $nN \times nN$
- $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$
- $a_{ij}^{RT} = z_{ij}^{RT} / x_j^T$

Multi-country Leontief inverse matrix *L*

- $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$
- $nN \times nN$
- $\mathbf{L} = l_{ij}^{RT}$

Multi-country environmental pressure coefficient vector *g'*

- $\mathbf{g}$
- $nN \times 1$
- $\mathbf{g}' = \mathbf{b}'\hat{\mathbf{x}}^{-1}$
- $g_i^R = b_i^R / x_i^R$

Variants of environmentally extended Leontief-type models

The general Leontief model

$$\bar{\mathbf{b}} = \mathbf{g} \cdot \mathbf{L} \cdot \mathbf{Y}$$

$\bar{\mathbf{b}}$ environmental pressure variable re-attributed to final demand

$\mathbf{g}$ vector of environmental pressure coefficients: ratios relating environmental pressure variable *b* to the output of the causing production activity

$\mathbf{L}$ Leontief matrix

$\mathbf{Y}$ final use matrix

Model variants - overview

There are numerous variants of the generic model equation.

- … providing different analytical perspectives,
- … answering different policy questions.

One may group the models into 3 clusters

Final use perspective

- Model variants that present the global amount of ’embodied’ environmental pressures **due to final use** primarily from the perspective of ...
  - a certain country of final use *S*,
  - a certain type of final use *p*,
  - combinations thereof (purpose *p* in country *S*).
- This cluster of model variants serves the classical ’consumption perspective’.
  - E.g. how much CO2-emissions are ‘embodied’ in households’ final consumption expenditures in France. Or, how much emissions are ‘embodied’ in the investment (gross fixed capital formation) in Italy.

Industry or final product perspective

- Model variants that present the global environmental pressures attributable to **industries due to their production of final products** delivered to global final use. Their results take primarily the perspective of ...
  - a certain host country *T*,
  - a certain class of industry *j*, and
  - combinations thereof (industry *j* in country *T*).
- This cluster of model variants is less often referred to.
  - E.g. how much global CO2-emissions are ‘embodied’ in all final products produced by metal manufacturing in China.

Source or production perspective

- Model variants that present the global ‘embodied’ environmental pressures while enabling to trace their initial source or driver. The results of those model variants may be used when primarily taking the perspective of ...
  - a certain source country *R*,
  - a certain source industry *i*, and
  - combinations thereof (industry *i* in country *R*).
- This cluster of model variants serves the classical ’production perspective’.
  - E.g. how much of the global ‘embodied’ CO2-emissions induced by France’s final use is emitted by metal manufacturing industry in China.

Model variants - overview

Model	Perspectives: variants:	Final use perspective	Industry or final product perspective	Source or production perspective
D	R.i.T.j.S.p.	X	X	X
A2	R.i.S.p.	X		X
C	T.j.S.p.	X	X	
B2	R.i.T.j.		X	X
A	S.p.	X		
B	T.j.		X	

Example: Model A

$$\bar{\mathbf{b}}' = \mathbf{g}' \cdot \mathbf{L} \cdot \mathbf{Y}$$

with:

$\bar{\mathbf{b}}'$	row vector of re-attributed emissions
$\mathbf{g}'$	environmental pressure coefficient row vector
$\mathbf{L}$	Leontief inverse matrix
$\mathbf{Y}$	final use matrix

- Final use perspective

Example: Model D

- *kN* equations:

$$\begin{matrix} \overline{\mathbf{B}_{\mathbf{1}}^{\mathbf{1}}} \\ \vdots \\ \overline{\boldsymbol{B}_{\boldsymbol{p}}^{\boldsymbol{S}}} \\ \vdots \\ \overline{\boldsymbol{B}_{\boldsymbol{k}}^{\boldsymbol{N}}} \end{matrix} = \begin{matrix} \hat{\mathbf{g}} \cdot \mathbf{L} \cdot \widehat{\mathbf{y}_{\cdot\mathbf{1}}^{\cdot\mathbf{1}}} \\ \vdots \\ \hat{\mathbf{g}} \cdot \mathbf{L} \cdot \widehat{\mathbf{y}_{\cdot\boldsymbol{p}}^{\cdot\boldsymbol{S}}} \\ \vdots \\ \hat{\mathbf{g}} \cdot \mathbf{L} \cdot \widehat{\mathbf{y}_{\cdot\boldsymbol{k}}^{\cdot\boldsymbol{N}}} \end{matrix}$$

with:

$\overline{\mathbf{B}}$	Matrix of re-attributed emissions
$\hat{\mathbf{g}}$	diagonalised environmental pressure coefficient vector
$\mathbf{L}$	Leontief inverse matrix
$\hat{\mathbf{y}}$	diagonalised final use vector

Data structure(s) for modelling results

Data models – general overview

Two basic data model concepts:

a) Multidimensional data cube

b) Relational database

The European Statistical System as well as the international SDMX standard employs the multidimensional data cube model a).

Data structure definition (DSD)

- DSD defines the n dimensions in a multidimensional data cube, i.e. the possible characteristics of a data point or record.
- Each dimension comes with a list of possible numeric or alphanumeric values that this dimension can take (code list).
    - E.g. the dimension ‘measurement unit’ can have codes such as ‘kilometres’, ‘pieces’, ‘kilowatt-hours’, etc.

DSD proposal (1)

- ...accommodating results of all possible Leontief-type model variants:

=> 10 dimensions

DSD proposal (2)

no.	Dimension label	no. of categories in FIGARO
1	Environmental pressure variable	5
2	Source country	46
3	Source industry	64
4	Country of final product	46
5	Industry of final product	64
6	Country of final demand	46
7	Category of final demand	5
8	Reference year	12
9	Measurement unit	2
10	Observation value	n.a.

Implementation issues (production, dissemination, communication)

Eurostat's multi-stage production system

- Primary or input stage
- Production stage includes the generation of the modelling results and storing them in a production database.
- Dissemination stage includes the publication of data in Eurostat's online data browser (Eurobase)

Eurostat's limitations (IT infrastructure)

- Production system (currently: MDT) able to manage data sets with up to 10 million records
- The Eurostat online data browser (dissemination system) can host data sets with up to 4 million records;
  limited to 6 dimensions in addition to the default observation value

Requirements (IT infrastructures)

		Environ-mental pressure indicator	Source country	Source industry	Country of final product	Industry of final product	Country of final demand	Category of final demand	Refer-ence year	Measur-ement unit	no. of records
			R.	i.	T.	j.	S.	p.			
R.i.T.j.S.p	Model D	5	46	64	46	64	46	5	12	2	239 212 953 600
R.i.S.p	Model A2	5	46	64			46	5	12	2	81 254 400
T.j.S.p.	Model C	5			46	64	46	5	12	2	81 254 400
R.i.T.j.	Model B2	5	46	64	46	64			12	2	1 040 056 320
S.p.	Model A	5					46	5	12	2	27 600
T.j.	Model B	5			46	64			12	2	353 280

Communication

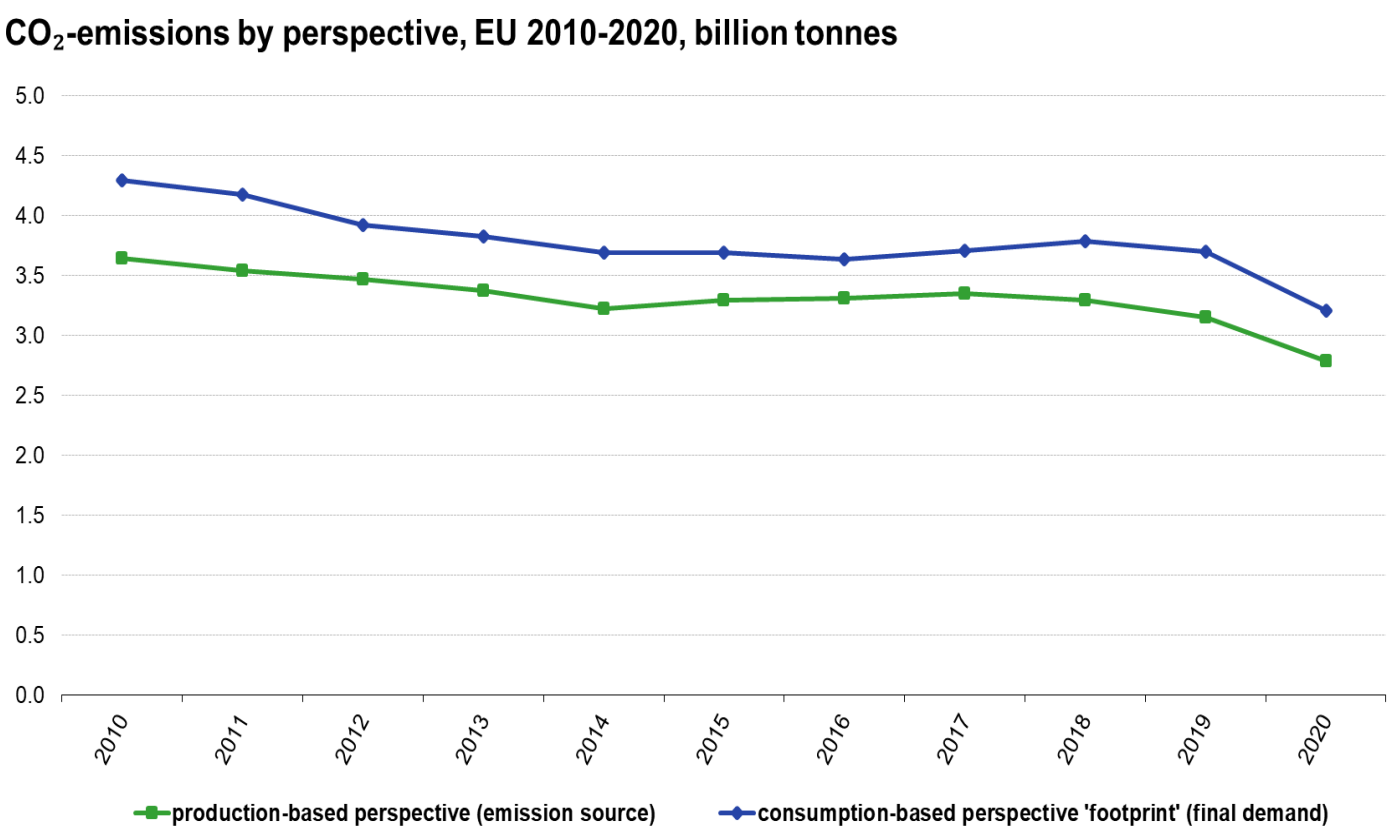
- Production system (currently: MDT) able to manage data sets with up to 10 million records
- The Eurostat online data browser (dissemination system) can host data sets with up to 4 million records;
  limited to 6 dimensions in addition to the default observation value

Communication: Carbon footprints (1)

- ... can mean many things (SEEA, national accounts)
- ... many analytical perspectives (10 dimensional data cube!)

Communication: Carbon footprints (2)

- In 2020, EU's consumption-based CO_2-emissions (carbon footprint) was 15% higher than its production-based.
- Over the last decade, both EU's consumption- and production-based CO_2-emissions decreased by around one quarter.



Source: Eurostat (env_ac_co2fp)

eurostat

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Communication: Carbon footprints (3)

- World-wide CO2-emissions: 34.4
- EU production-based: 2.8
- EU consumption-based 3.2

Global CO_2-emissions - EU vis-a-vis the rest of the world, 2020, billion tonnes

	serving EU's consumption (final demand)		serving consumption (final demand) in the non-EU rest of the world		Total produced	
produced in EU	2.3	7%	0.5	2%	2.8	8%
produced in the non-EU rest of the world	0.9	3%	30.7	89%	31.7	92%
total consumed:	3.2	9%	31.2	91%	34.4	100%

Source: Eurostat (env_ac_co2fp)

Summary

Multi-regional IO modelling:

- quite complex application technique
  => guidelines for modelling
- requires adequate IT infrastructures
- complex data structure: communication challenge (‘footprint’)

Questions for discussion

Dissemination: How to best cut the data cube?

Challenge: to communicate the complex data structure

Thank you!

stephan.moll@ec.europa.eu

European Commission