Workshop on Assessing The Impacts Of Environmental Regulation
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Linking Input-Output Model With Material Flow Analysis

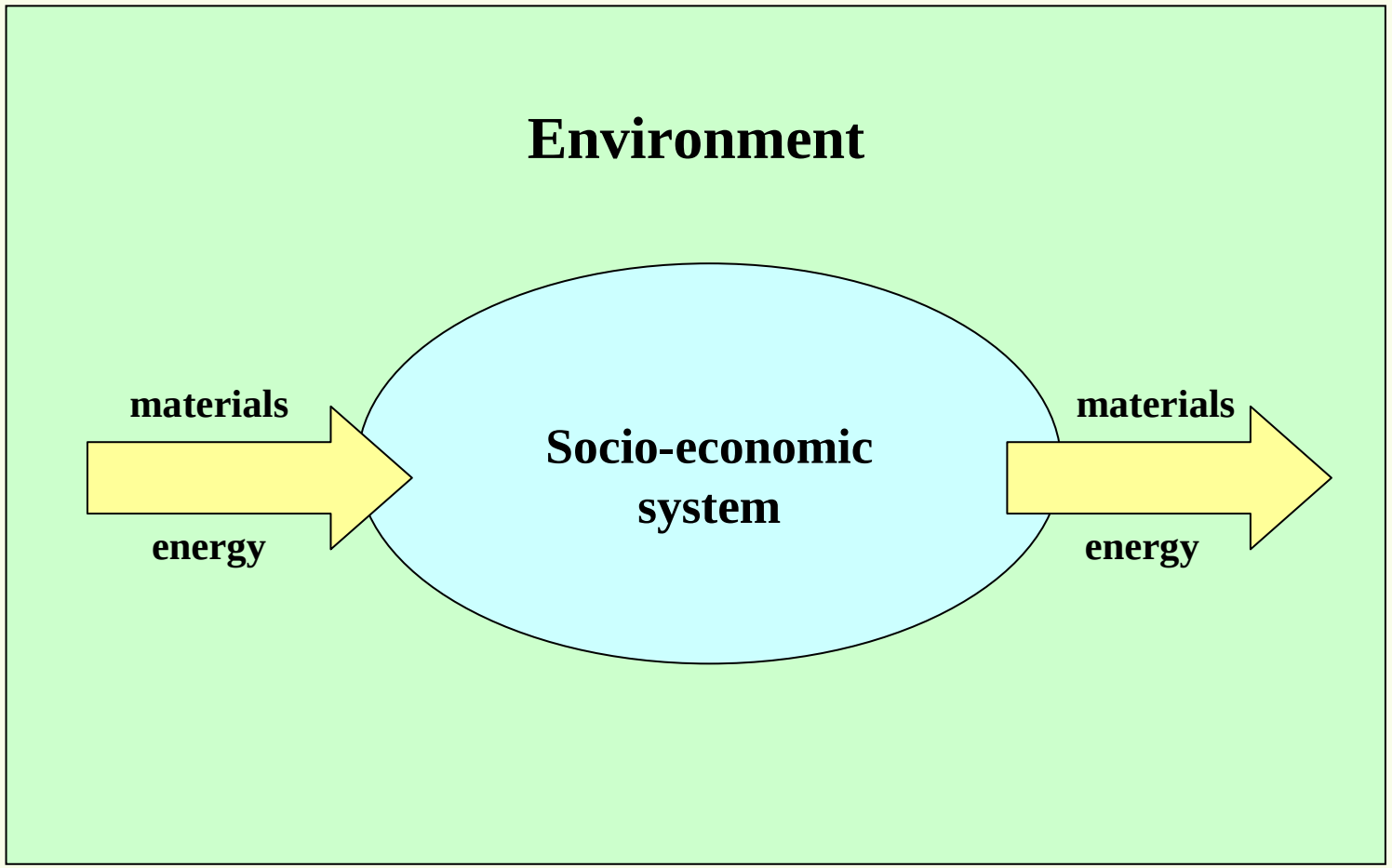
Jan Weinzettel and Jan Kovanda

Charles University Environment Center

Outline

- Purpose of material flows accounting
- Input output formulation of process LCI
- Environmentally extended input output analysis
- Multiregional input output models
- Hybrid LCA and its use in EW-MFA
- Structural decomposition analysis

Socio-economic metabolism an overview



Source: Eurostat, 2001, modified

Material flows accounting and indicators

- Developed in the 1990‘s by group of organizations including Eurostat, WRI, Wuppertal Institute, National Institute for Env. Studies in Japan, Institute for Interdisciplinary Studies of AU
- Based on the assumption that the environmental pressure is related to total mass of materials which are exchanged between socioeconomic system and its environment

- → it is possible to use material flows indicators as indicators of the environmental pressure by the humans
- Examples of indicators
  - Direct Material Input (DMI): sum of used domestic extraction and imports.
  - Domestic Material Consumption (DMC): DMI minus exports.

Raw material equivalents and embodied emissions

- A tendency to
  - express product flows across national boundaries in terms of natural resources used for its production in order to account for global env. pressures and to prevent apparent improvements due to shifts of dirty processes outside the country
  - To account for embodied emisisons (emissions from the whole production chain)

Methods for RME and embodied emissions estimation

- Life cycle inventory (LCI)
  - Too many different products
- Environmentally extended input output analysis
  - Only suitable for products with equivalent domestic production
- Multiregional input output analysis
- Hybrid LCA

Matrix expression of LCI

Process flows		Demand							
		Coal extraction	Iron ore extraction	Steel production	Electricity generation	Train production	Train transport	Product output (y)	Total (x)
Supply	Coal extraction (kg)	10	20	100	500	0	0	200	830
	Iron ore extraction (kg)	0	0	500	0	0	0	50	550
	Steel production (kg)	50	50	20	10	300	0	100	530
	Electricity generation (kWh)	20	10	50	20	100	100	0	300
	Train production (pieces)	0	0	0	0	0	10	0	10
	Train transport (ton.km)	600	200	50	0	20	0	10 000	10770
Elementary flows									
Coal in ground (kg)		830	0	0	0	0	0		
Iron ore (kg)		0	1 200	0	0	0	0		
CO2 (kg)		100	20	300	1000	0	0		
SO2 (g)		2	0,1	0	0	0	0		
Nox (g)		5	2	20	30	0	0		
Noise in pop. area (€)		0	0	0	0	0	100		

Z **y** **x**

F_r

Matrix calculation of LCI

- Model of the production process - technology coefficients and intensity matrix:

$$A = Z \,.\, (\mathrm{diag}(x))^{-1}$$

$$F = F\_r \,.\, (\mathrm{diag}(x))^{-1}$$

- Total process flows related to particular products y:

$$x = (I - A)^{-1} \,.\, y$$

  y can be exchanged by any vector of products

- Total elementary flows related to process flows and products (= LCI data):

$$E = F \,.\, x$$

$$E = F \,.\, (I - A)^{-1} \,.\, y$$

Environmentally extended IOA

Intersectoral monetary flows		Demand							
		Agriculture	Forestry	Fishing	Mining	Manufacturing	Services	Final demand (y)	Total (x)
Supply	Agriculture (€)	10	20	100	500	0	0	200	830
	Forestry (€)	0	0	500	0	0	0	50	550
	Fishing (€)	50	50	20	10	300	0	100	530
	Mining (€)	20	10	50	20	100	100	1	
	Manufacturing (€)	0	0	0	0	0	10	0	10
	Services (€)	500	200	50	0	20	0	10 000	10770
Elementary flows									
Coal in ground (kg)		500	0	0	0	0	0		
Iron ore (kg)		0	1 200	0	0	0	0		
CO2 (kg)		100	20	500	1000	0	0		
SO2 (g)		2	0,1	5	0	0	0		
Nox (g)		5	2	20	30	0	0		
Noise in pop. area (€)		0	0	0	0	0	100		

Z **y** **x**

F_r

Multiregional IOA

- Ussually monetary tables with environmental extension
- For one year only, update very demanding
- Very useful and strong tool for focusing on global flows

$$Z = \begin{pmatrix} \mathbf{Z_{11}} & Z_{12} & Z_{...} & Z_{1n} \\ Z_{21} & \mathbf{Z_{22}} & Z_{...} & Z_{2n} \\ Z_{...} & Z_{...} & \mathbf{Z_{...}} & Z_{...} \\ Z_{n1} & Z_{n2} & Z_{...} & \mathbf{Z_{nn}} \end{pmatrix}$$

Units in IOA

- As it is used in LCI, the units in IOA can be both monetary, and physical
- It is possible to make hybrid IOT
  - Some product groups are expressed in monetary units, others in physical, e.g. tons, Joule, etc.
- One row = one type of units
- It is possible to disaggregate product groups according to desired characteristics

Hybrid LCA

$$Z = \begin{pmatrix} Z_{proc} & Z_{p \to IOT} \\ Z_{IOT \to p} & Z_{IOT} \end{pmatrix}$$

Expression of MFA indicators in RME

$$DMI_{RME} = F \,.\, (I - A)^{-1} \,.\, y_{tot}$$

$$DMC_{RME} = F \,.\, (I - A)^{-1} \,.\, y_{dom}$$

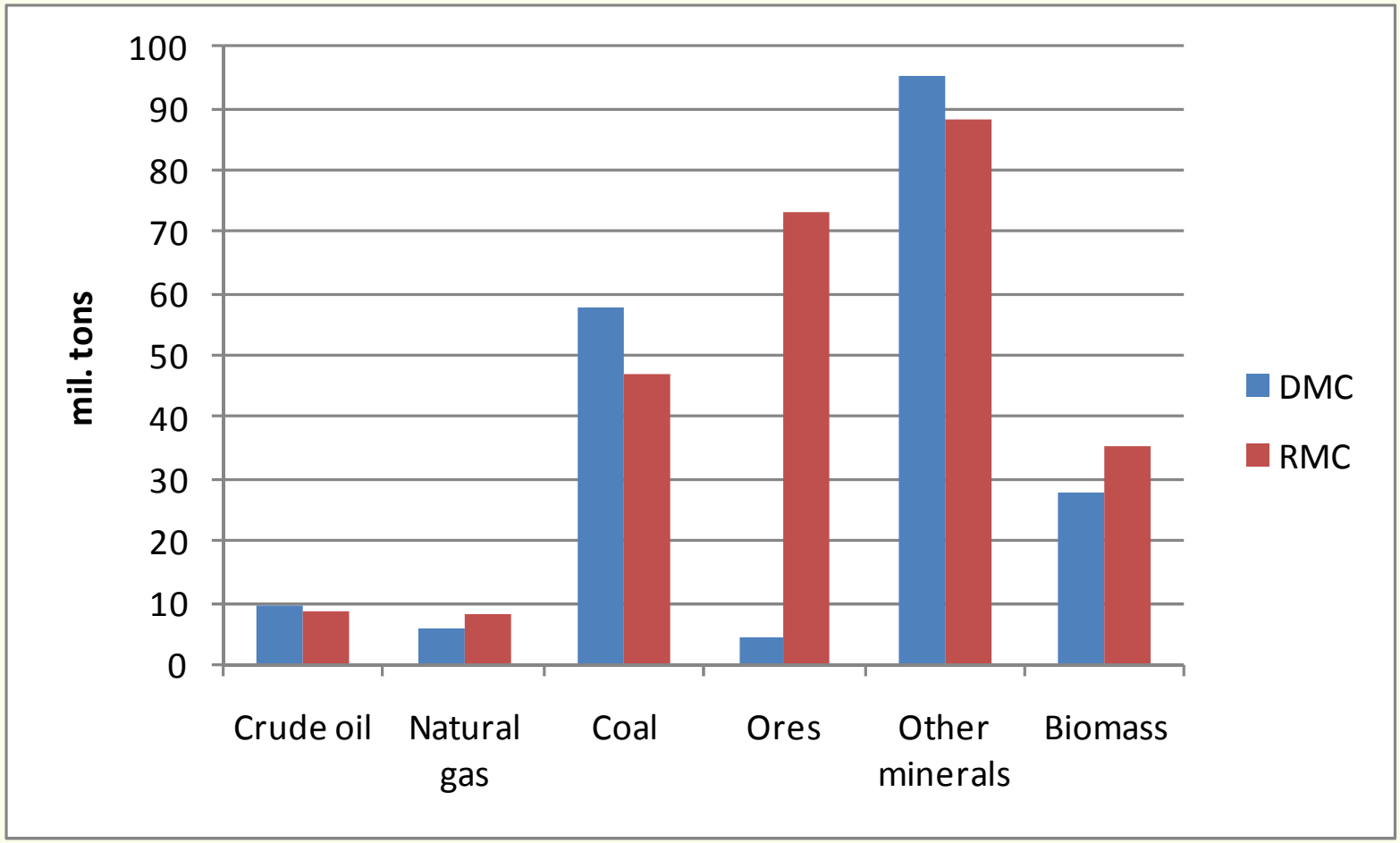
$$IMPORT_{RME} = F \,.\, (I - A)^{-1} \,.\, IMPORT$$

$$EXPORT_{RME} = F \,.\, (I - A)^{-1} \,.\, EXPORT$$

Eurostat RME project

- Based on 60 x 60 monetary IOT
- Extended into 115 x 115 hybrid IOT (e.g. metals, agriculture, crude oil and natural gas, and others)
- LCI data for crude oil, natural gas, metal ores, and basic metals
- It is very useful to disaggregate some specific sectors

Comparison of traditional and RME indicators (Czech Republic, 2003)



Comparison of traditional and RME indicators

Direct flows x

- Regional view
- Cannot capture shifts in production site
- Data collected by national statistical offices

Direct + Indirect flows

- Global view
- It is possible to assign flows to consumption (the driving force)
- Difficult to express (not one commonly agreed methodology)
- Data demanding

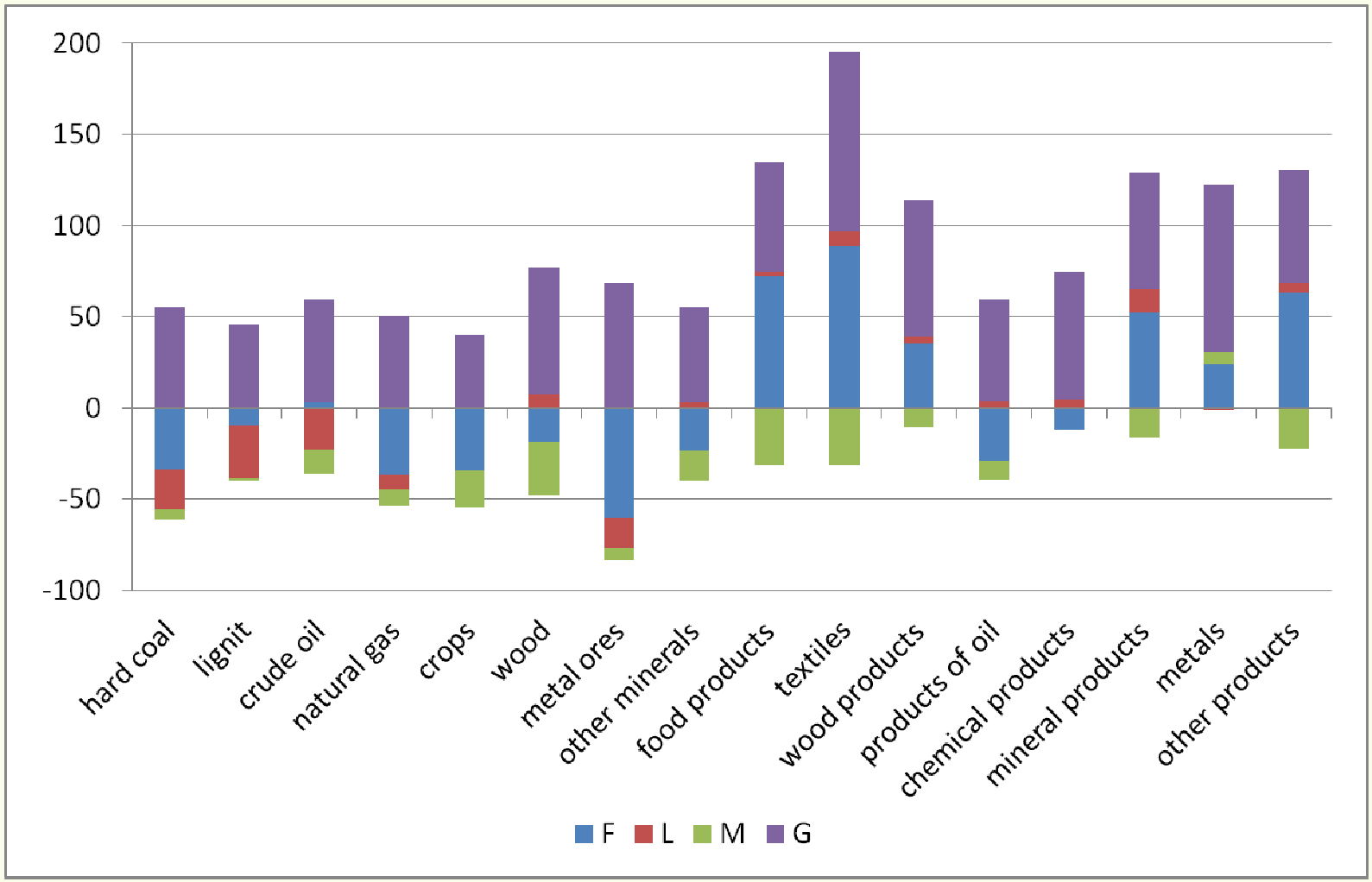
Structural decomposition analysis

- To analyze changes in time or difference between two countries
- Based on expression of material flows using Leontieff inverse

$$DMI = F \cdot L \cdot M \cdot G$$

$$L = (I - A)^{-1}$$

SDA of DMI
(Czech Republic, 2000 – 2007)



Concluding remarks

- IOA is suitable tool to understand better the socioeconomic metabolism, and the driving forces for material flows and their changes over time
- It is not suitable for simulation of policy actions, but it has the advantage of high sectoral resolution
- Environmentally extended IOA and hybrid LCA can be also used to estimate emissions embodied in final demand products, and therefore it can be used for a rough estimate of the impact of environmental taxes on the prices of products

Thank you for your attention!

Any questions are welcome.

Feel free to contact me at:
jan.weinzettel@czp.cuni.cz