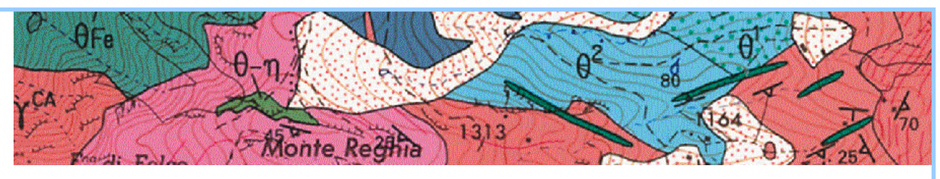

Environmental Input-Output Analysis: Hybrid Monetary-Physical vs. Monetary models. Differences highlighted considering French final consumption

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Context

- Hybrid process/Input-Output (IO) LCA is claimed to provide better system completeness than process-LCA by avoiding arbitrary cut-offs
- Monetary Input-Output Tables (MIOT) are regularly provided by national statistical services
- A considerable amount of process Life Cycle Inventories are available in physical units (mass, energy) in standard databases, and could be integrated within Hybrid Monetary-Physical Input-Output Tables for hybrid process/IO LCA

Study objectives

- Re-visiting the construction of Hybrid Monetary-Physical Input-Output Tables, using constrained optimization techniques
- Applying environmental Input-Output Analysis to calculate the fossil CO_2 emissions and basic metals embodied in the French final consumption, using two approaches: purely Monetary and Hybrid Monetary-Physical

Methodology

Tables Framework

- Environmentally-extended Physical Supply Use Tables (PSUT) are compiled:
  - considering France for the year 2006
  - distinguishing 59 activities and their corresponding 59 product categories according to the NACE nomenclature rev 1.1
- Monetary Supply Use Tables are taken from Eurostat

Table 1
Theoretical framework of balanced PSUT

	Activities	Imports	Final consumption	Exports	Total
Products	V'	N			q
Total	g'				
Products	U		Y	E	q
Stock changes	-ΔS				
Supply of residuals	$-W_v$				
Use of residuals	W_u				
Resources	R				
Emissions	-B				
Total	g'				

PSUT comply with accounting identities based on the material balance principle, on a product and on an activity perspective:

$$\sum_{j=1}^{n} V'(i,j) + N(i) = \sum_{j=1}^{n} U(i,j) + Y(i) + E(i) = q(i) \qquad \text{Equation 1}$$

$$\sum_{i=1}^{n} V'(i,j) + \sum_{i=1}^{wf} [W_v(i,j) + \Delta S(i,j)] + \sum_{i=1}^{b} B(i,j) = \sum_{i=1}^{n} U(i,j) + \sum_{i=1}^{wf} W_u(i,j) + \sum_{i=1}^{r} R(i,j) = g'(j) \qquad \text{Equation 2}$$

Tables compilation: from inconsistent PSUT to Hybrid Monetary-Physical IO Table

Data mining

- Initial PSUT compilation
- Data accuracy estimation

Data collection from different sources, completed with conversion operations, aggregation/disaggregation, estimations

➧ Inconsistencies in mass balances

PSUT reconciliation

Objective function

Reconciled PSUT

Hybrid Physical-Monetary Input Output Table

PSUT reconciliation: a constrained optimization approach

Goal

Finding estimators which are:

- Consistent with mass balance constraints
- Close to initial values, as a function of the data accuracy

Objective function

- **Weighted least-squares**

$$Min \sum_{i=1}^{n} w_i \left(\frac{x_i - \hat{x}_i}{x_i} \right)^2$$

w_i: accuracy of the measured value
x_i: measured value
$\hat{x}_i$: estimator

Constraints

- **Mass balance equations and inequations**

$$g_k(\hat{x}_i) = 0 \qquad i = 1, \dots, n$$
$$g_l(\hat{x}_i) < 0$$

Environmental Input-Output Analysis

The fossil CO_2 emissions embodied in the French final consumption (y) are calculated according to:

$$b = B_A (I - A)^{-1} y \qquad \text{Equation 3}$$

A: direct requirement matrix, purely Monetary or hybrid Monetary-Physical, B_A: vector of fossil CO_2 coefficients per Meuros or ktonnes output of each sector

Results

Figure 1: Mapping representation of the French Physical Use Table (the exchanges of products in the French economy), considering the 32 product categories quantifiable in physical units (ktonnes) and all 59 activities

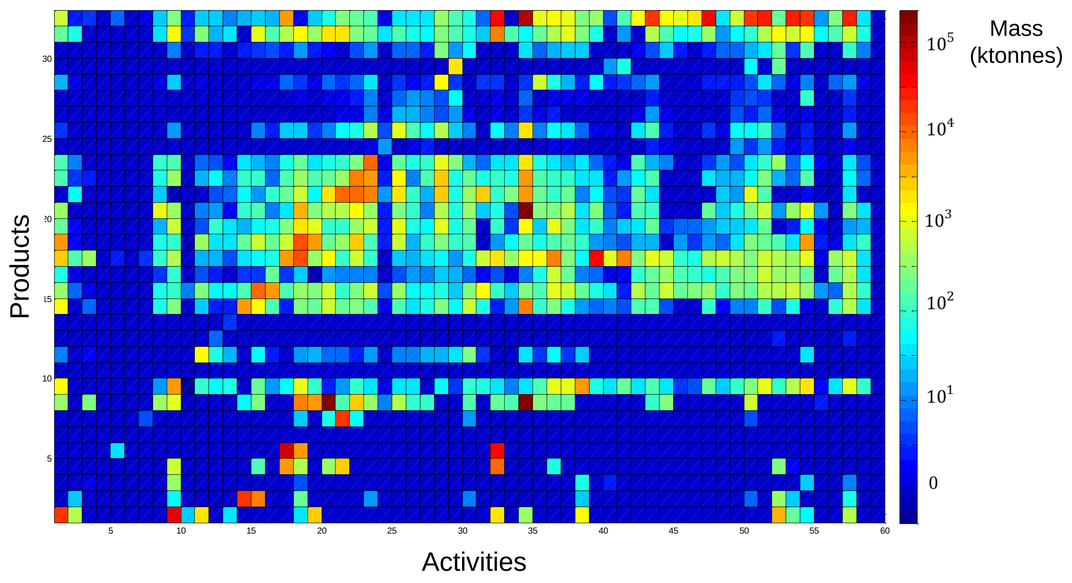

Table 3: Fossil CO_2 emissions and basic metals consumption embodied in the French final consumption, in 2006 – comparative analysis based on Monetary IO and Hybrid Monetary-Physical IO

	Monetary IO Analysis	Hybrid Monetary-Physical IO Analysis
Fossil CO_2 emissions	372 Mtonnes	432 Mtonnes
Basic metals consumption	29.4 Geuros	62.5 Mtonnes

Table 2: The French Hybrid Monetary-Physical IO Table: focus on the direct and total (direct + indirect) consumption of products for the production of 1 ktonne of "motor vehicles, trailers and semi-trailers" – main consumptions only

	Direct consumptions (in ktonnes)	Total consumptions (in ktonnes)
Rubber and plastic products	0.117	0.257
Basic metals	0.355	1.621
Fabricated metal products	0.300	0.749
Machinery and equipment	0.123	0.332
Electrical machinery and apparatus	0.067	0.127
Motor vehicles, trailers and semi-trailers	0.167	1.208

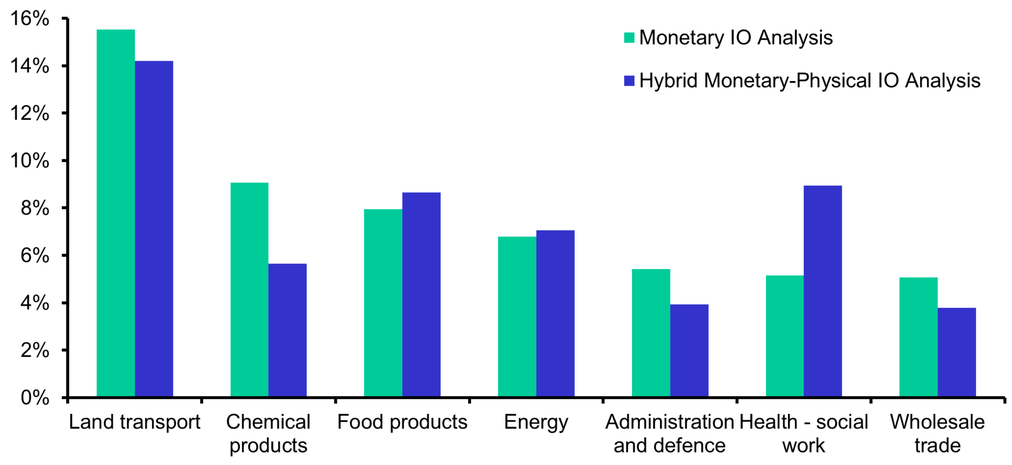

Figure 2: Total fossil CO_2 emissions embodied in the French final consumption. Products contributions to the total impact, considering Monetary IO and Hybrid Monetary-Physical IO Analysis – main contributions only

Conclusion and perspectives

1) The presented reconciliation technique enables to compile **consistent Physical Supply Use tables,** accounting for **data accuracy**

2) Environmental Hybrid Monetary-Physical IO Analysis and Monetary IO Analysis:

- **result in relatively different embodied environmental impacts** (fossil CO_2 in the case study)
- **convey different types and levels of uncertainty**, in terms of (Hawkins et al., 2007) source data, proportionnality assumption, aggregation, imports assumption, environmental multipliers and model input (functional unit, final demand)

➧ **using both models (instead of 1 model only)** to derive ranges of environmental impacts

➧ **uncertainty propagation in Monetary and Hybrid Monetary-Physical IO Analysis** as a key point to be dealt with in depth in future studies

3) The development of Hybrid Monetary-Physical IO Tables, still facing limits (in particular the difficulty in data compilation), would enable:

- **to widespread the application of Hybrid process/IO-LCA**, by facilitating the integration of LCI process data within IO Tables
- **to ease IO analysis with respect to specific activities and materials** (such as, respectively, waste management and metals)

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References: Hawkins, T., Hendrickson , C., Matthews, S., 2007. Uncertainty in the Mixed-Unit Input-Output Life Cycle Assessment Model of the US Economy. 16th International Input-Output Conference