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IPS 224
Harnessing The Power Of Input-Output Analysis For Sustainability

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Introduction

Carbon content measurement: national level, sectoral level, company level, product level

Principal issue: indirect emissions – (Scope 3 emissions cradle to gate) emissions attributed to production inputs, and their inputs, and…

Input-Output (IO) analysis is an established technique to model and quantify **interactions between units of production.**

Data Gaps initiative within the G 20: The new DGI has **3 recommendations focussing on production interactions and carbon footprints:** recommendations on **IO and carbon emission statistics,** on **energy accounts** and **direct investment carbon footprints.**

How can national and international IO frameworks be adjusted for use in sustainability?

IO and Scope 3 emissions – how does it work?

Consider the *bill of material* (BoM) of product *k*, with $a_{k,i}$ being the quantity of good *i* embodied in the production process:

$$\mathbf{a}_k = (a_{k1} \quad a_{k2} \quad \dots \quad a_{kK})'$$

Let d_k be the amount of GHG directly emitted and c_i be the carbon content of input *i*

direct emissions

indirect emissions

value structure

Then the carbon content of good *k* is given as the **sum of direct and indirect emissions**:

Carbon content vector

quantity structure

$$c_k = d_k + \mathbf{c}'\mathbf{a}_k = d_k + \sum_i c_i a_{ki} \qquad (1)$$

If the c_i are known, we can calculate the carbon content of product k directly.

IO and Scope 3 emissions – how does it work?

If the g_i are unknown, the equation is **recursive**. Equation (1) is an **IO model for production**. We can solve for the GHG value of all products simultaneously. Let

$$\mathbf{A} = (\mathbf{a}_1 \quad \mathbf{a}_2 \quad \dots \quad \mathbf{a}_K)$$

be the matrix of the BoMs for all produced goods. With **d** the vector of direct emissions for products 1,…, *K*, we may write:

$$\mathbf{c}' = \mathbf{d}' + \mathbf{c}'\mathbf{A}$$

and solving for **c** yields

$$\mathbf{c}' = \mathbf{d}'(\mathbf{I} - \mathbf{A})^{-1} \qquad (2)$$

Carbon contents of all goods

Direct emissions for all goods

Leontief inverse, reflecting production interlinkages

The task

- Data on interlinkages exist, on a sectoral level, from national and international Input-Output tables.
- Can be used to compute proxies for the firm level and the product level
- Conceptually, these proxies embrace all the relevant interactions.
- With finer (and more relevant) sectoral distinctions, the carbon content measurement may get more exact

How should IO evolve to be of good use for carbon content measurement?

The task

- Ideally, we should have company- or product level data containing "true" data on direct and indirect emissions.
- Then we could look and see how aggregate statistics need to be enhanced and developed to yield better proxies
- We do not have that kind of micro data. But we can simulate them!
- Von Kalckreuth (2022): simulation for Germany solely on the basis of IO information, for a different purpose.

The task

This project simulates micro level emissions on the basis of "true" micro level information on (a) direct emissions and (b) electricity use, combined with model based outcomes for indirect emissions, from production interactions

- Macro level database: BEA Input Output data: 405 sectors for 2012, and 71 sectors for 2018. to be replaced by 405 sectors for 2017 as soon as they become available
- Micro level database: commercial company-level data on US economy for 2020
- Linking micro data to aggregate data on sales or energy use, we can determine (survey) weights for the companies – providing a simplified image of the overall US economy

A laboratory for assessing a large range of measurement questions

What can be investigated?

- Direct emissions and energy consumption **are "real"**

- With **405 sectors**, the BEA Input-Output Tables are **far more detailed** than any conceivable international IO data base.

- Trying to approximate the outcomes of the simulated micro data with aggregate statistics will tell us the direction, in which productivity gains can be made:
  - More and finer sectors?
  - In what areas? Different sources of energy?
  - The value of taking international linkages into account?
  - The value of having sector level approximations for the carbon content of inputs in carbon accounting?

Done

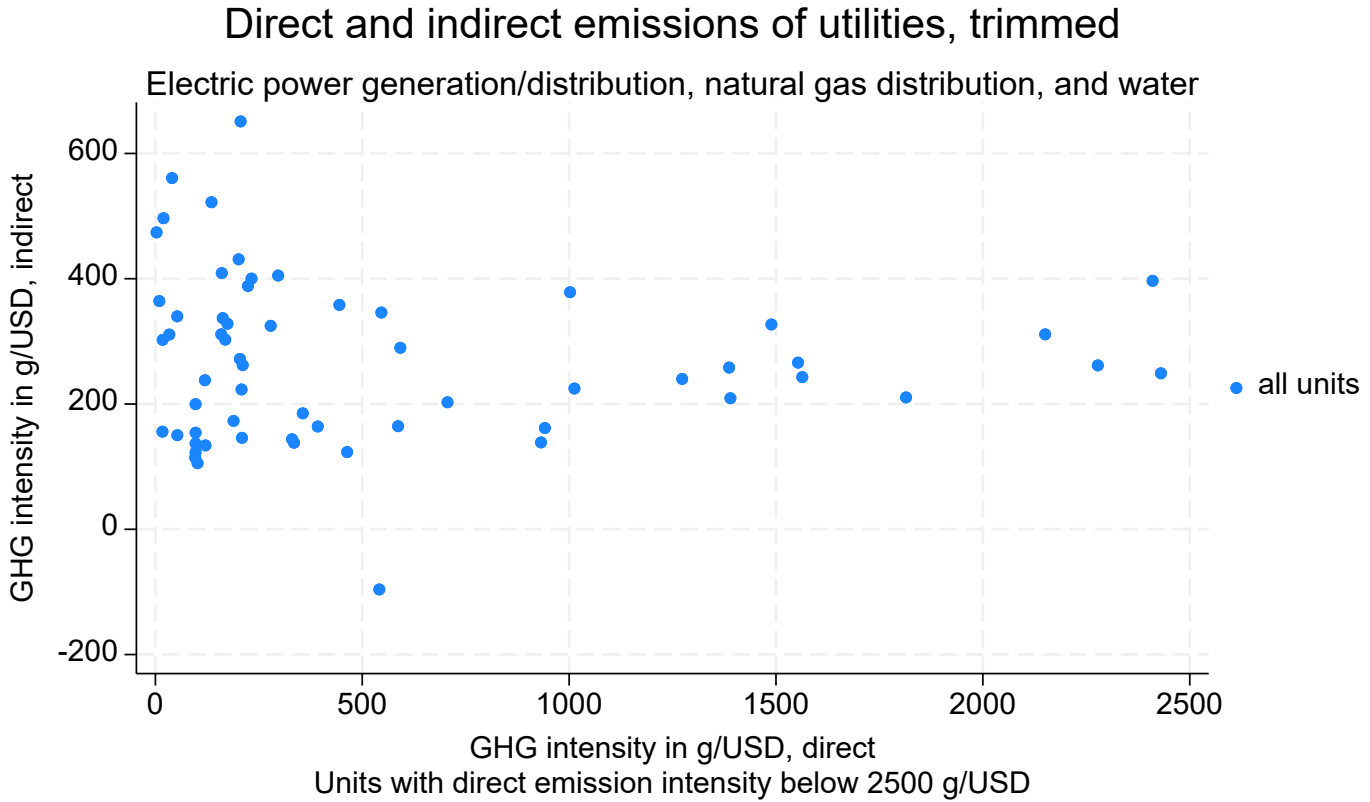
- Extrapolated detailed level IO matrix for 2020
- Correspondence micro industries -- BEA (both rely on NAICS) -- **hard work!**
- 5041 micro level units for 2020, 97.16% of these from USA or Canada
- 390 BEA-industries on the "detailed" level and 67 industries on the "summary" level
- Missing: Most of government activity, private households, religious organisations and independent artists / writers / performers
- Micro level IO table by drawing units from the respective input sectors at random for each unit, disregarding the missing government sectors
- Micro level Leontief matrix

- Simulation: carbon content of output for all units

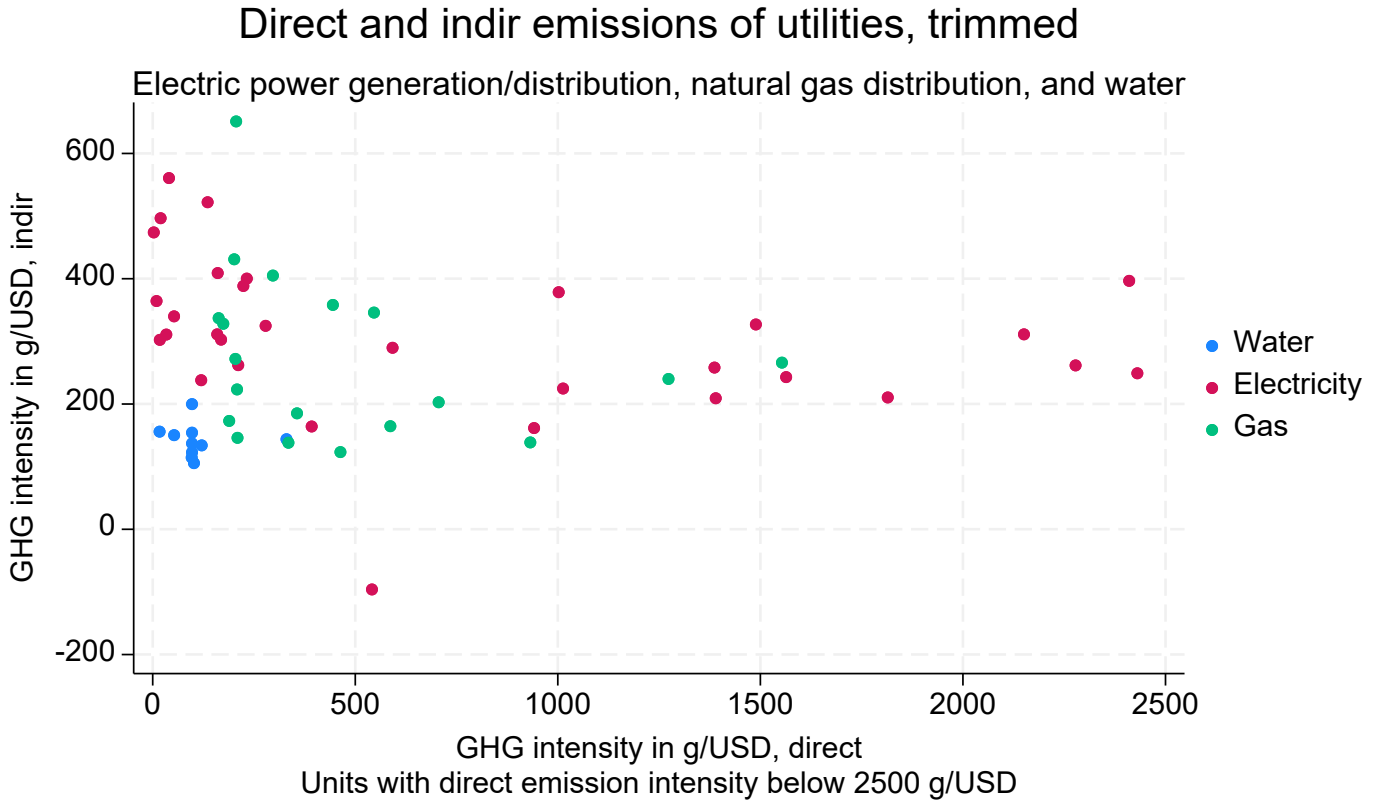
To do

- Make use of unit level data on scope 2 emissions
- Weighting by energy use or sales
- Introduce stochastic variation in requirement coefficients
- Systematic evaluation work!

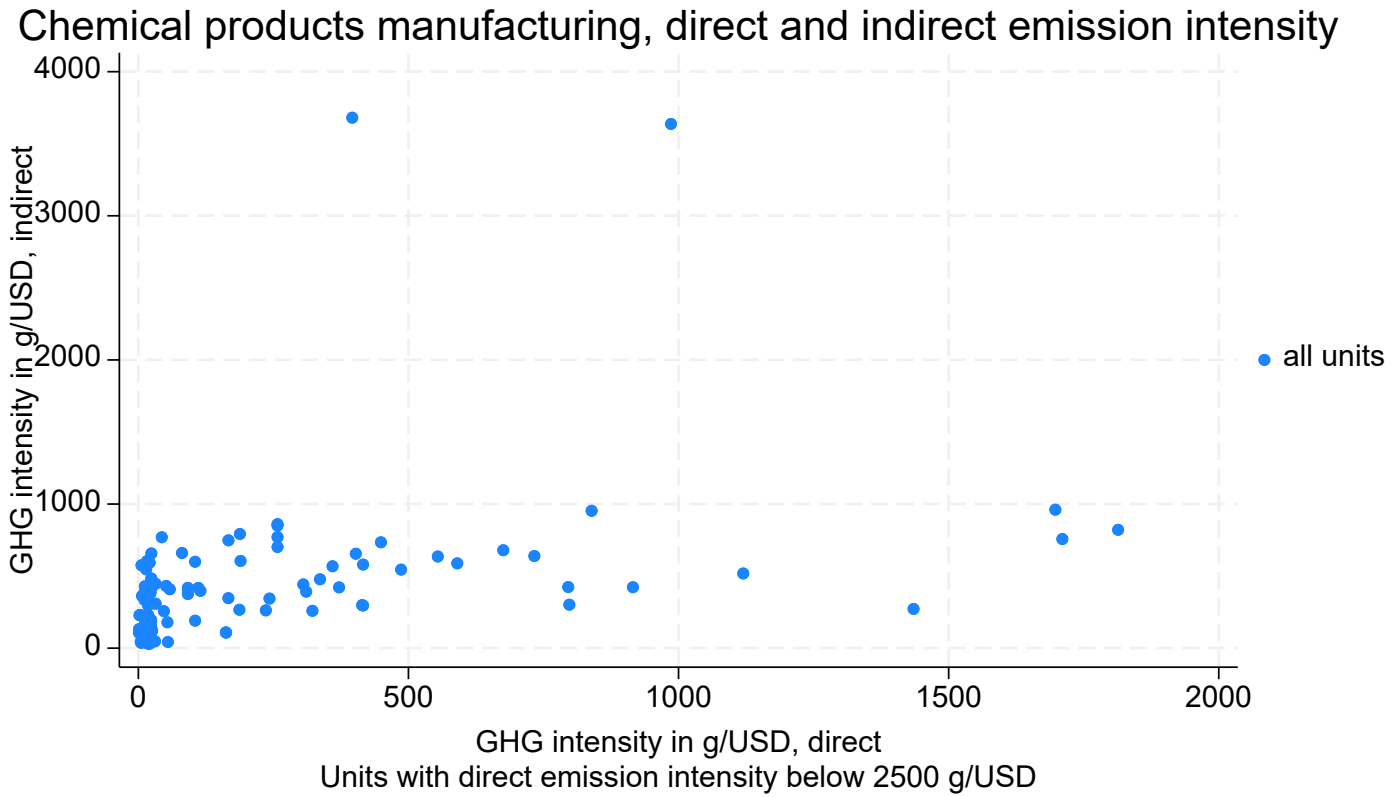
A glimpse: Utilities (1)



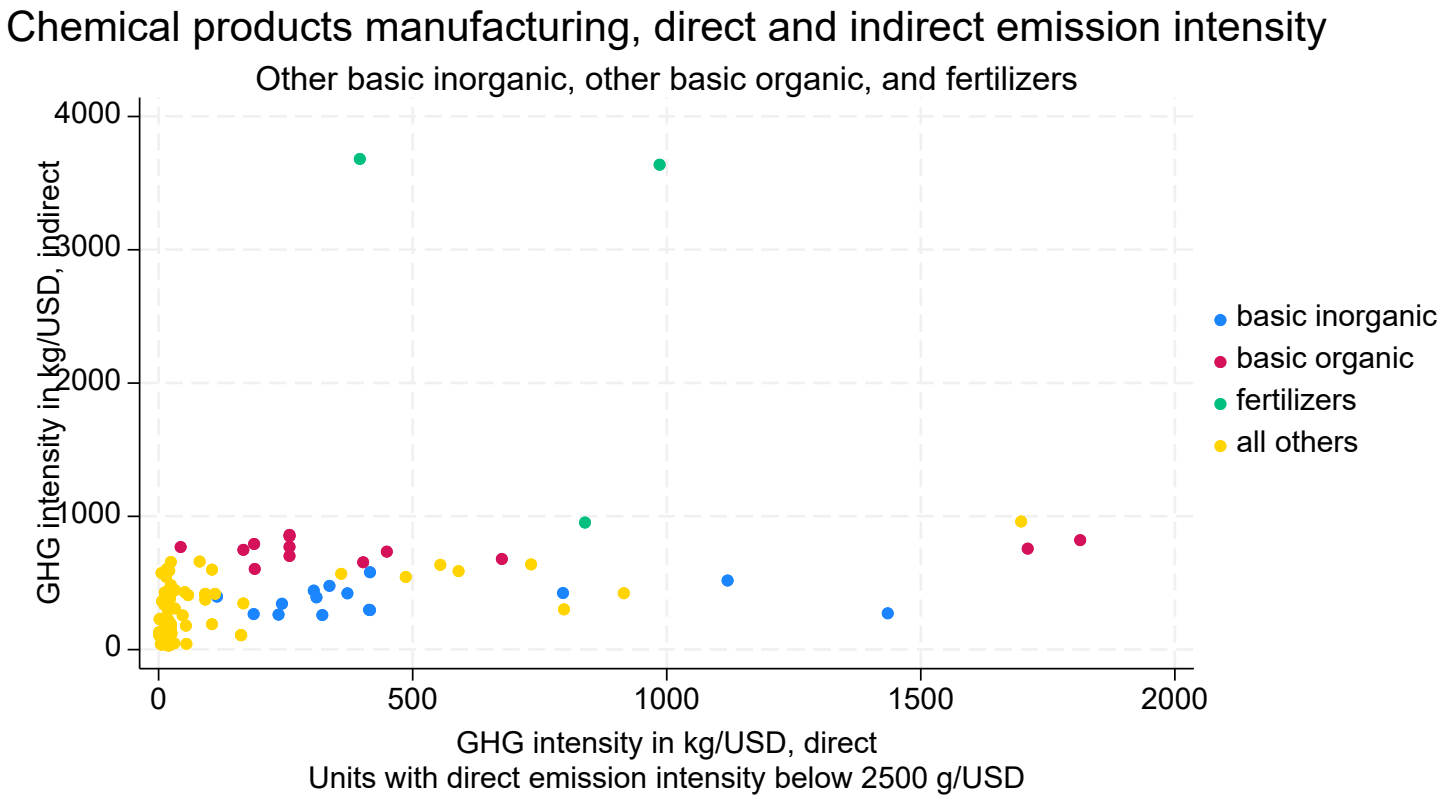
A glimpse: Utilities (2)



A glimpse: Chemical products



A glimpse: Chemical products



Outlook

- Compute the average error associated with any measurement method, based on the knowledge of the simulated “truth”.

- This amounts to setting up an infrastructure that will enable us to discuss measurement issues consistently and on a quantitative basis.

- This project is related to a **planned workshop on carbon content measurement** on a sectoral level, firm level and product level in February 2024 in Hamburg

- Organised by BIS, the IMF, Eurostat, Banco de Chile, the University of Oxford, with the E-Liability Institute as operating partner