Estimating the world ICT carbon footprint trajectory over the 2010-2019 decade

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Outline

- Methodology (*)
- 2010-2019 trajectories (**)
  - Europe and Rest of the World structures
  - ICT and subsectors
- Appendix
  - Other sectors' production footprint over the decade
  - More on methodology

(*) Estimating the Carbon Footprint of ICT Using Input-Output Analysis: Dealing with Overcounting and Other Challenges, Charpentier,Martins,Bourcier, Conf. ICT4S June 2023, Rennes

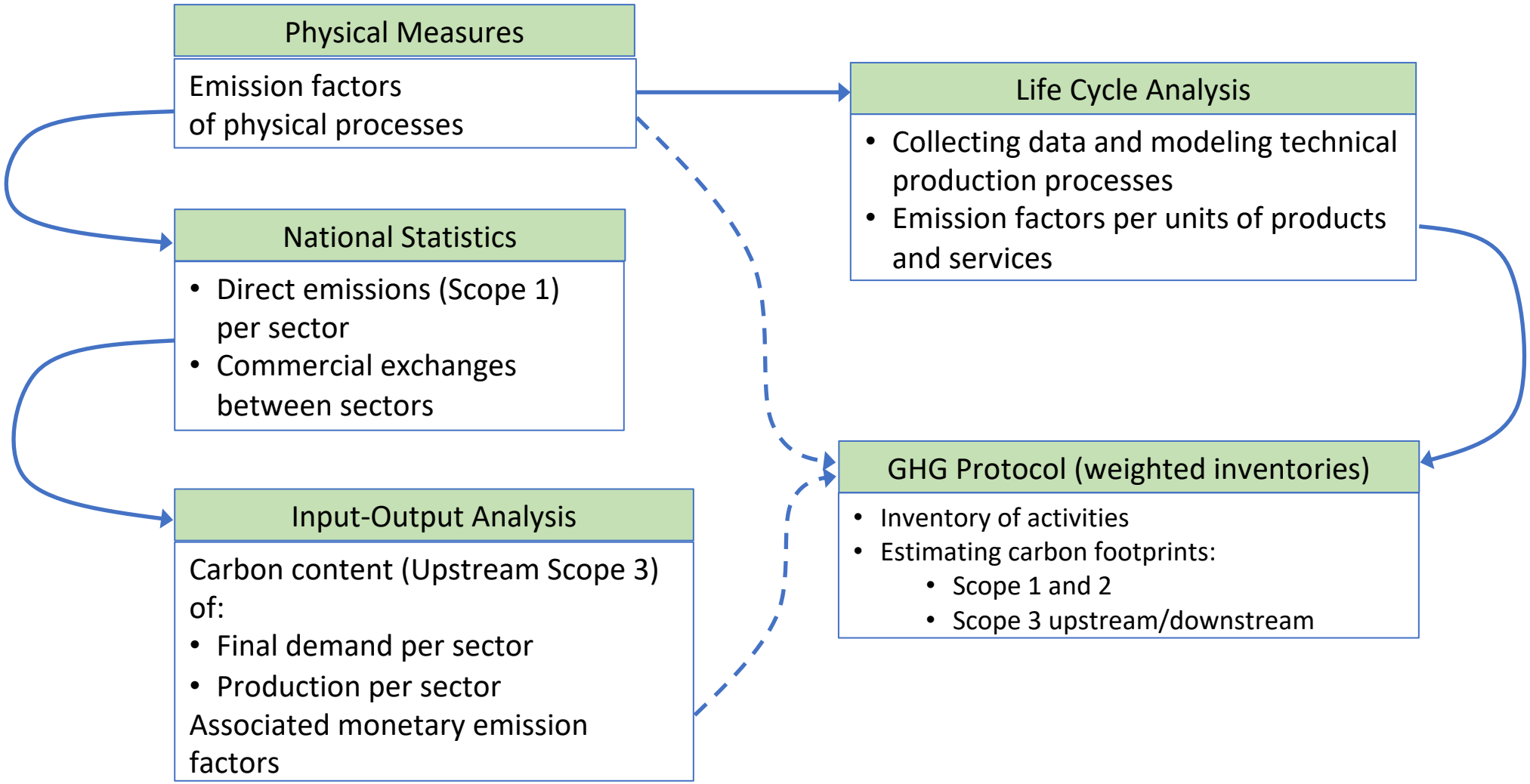
(**) Analyzing production footprints of economic sectors over the 2010-2019 decade, Blain & Charpentier, 2nd Conference Action vs. Inaction facing Climate Change, 17-18 June 2024, Strasbourg

Methodology

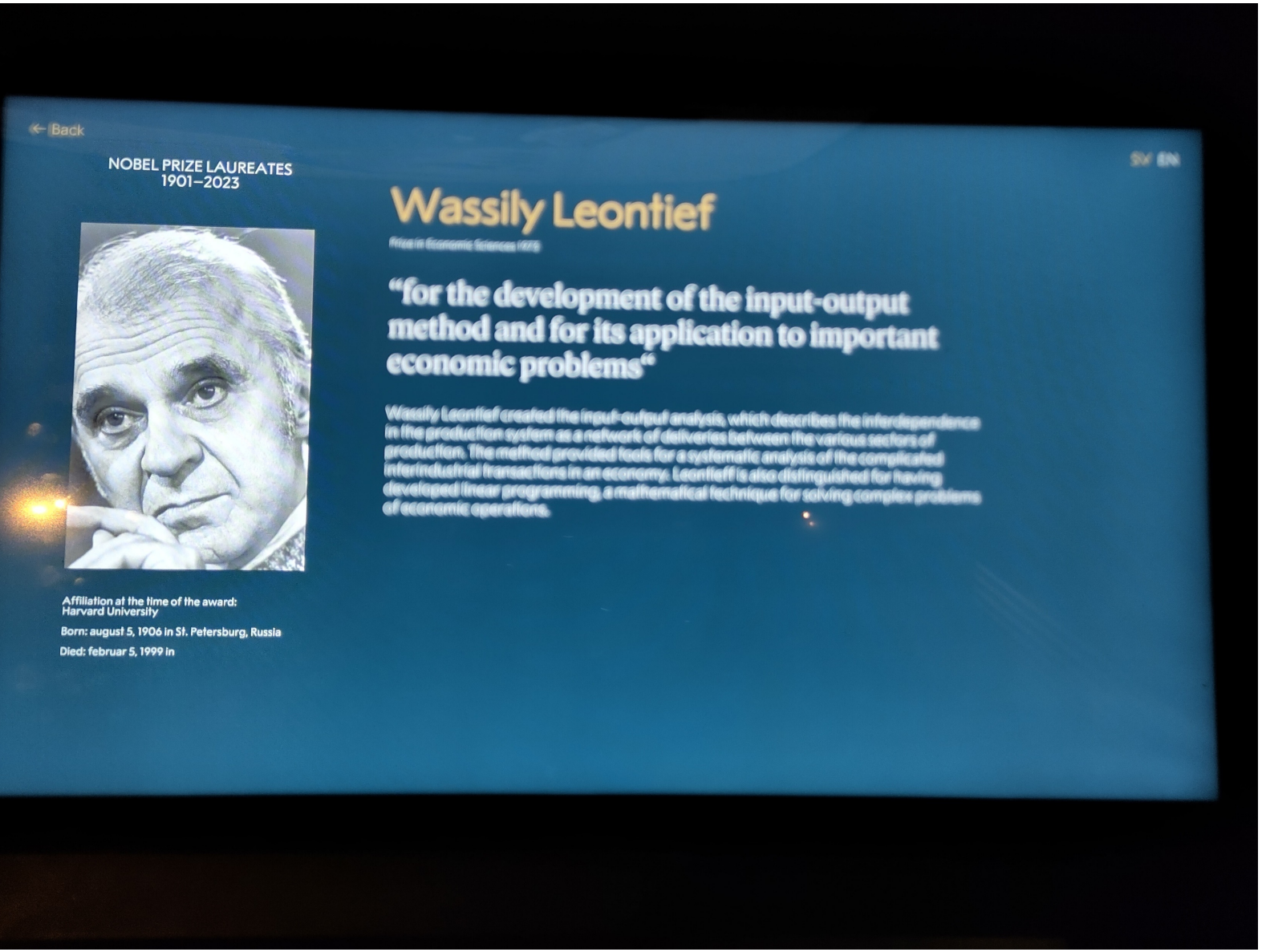
- Overview

- Main indicators

Overview of carbon footprint methodologies



Input-ouput method introduced over 50 years ago



Economy « Nobel prize » in 1974

A photo taken yesterday at the museum of Nobel prizes in Stockholm

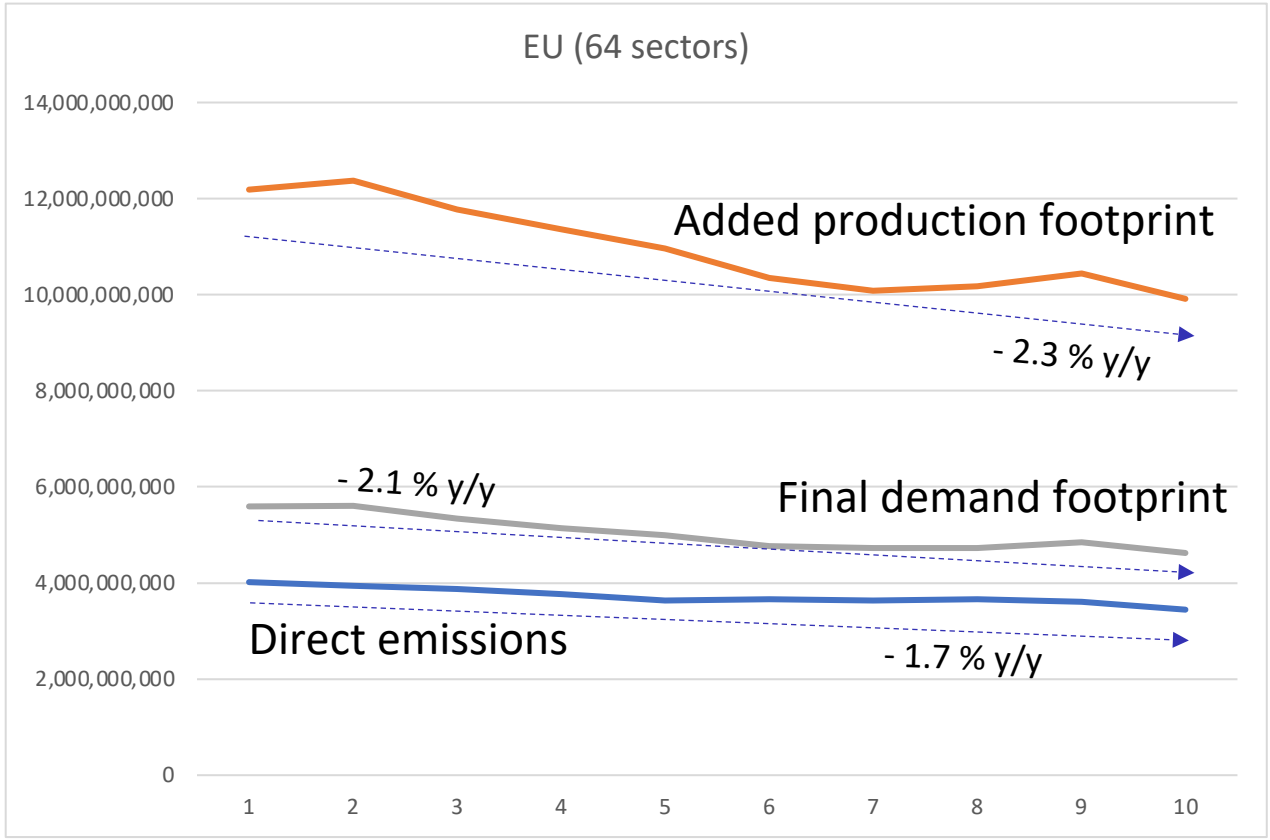
Indicators to analyse the carbon footprints of an economic sector

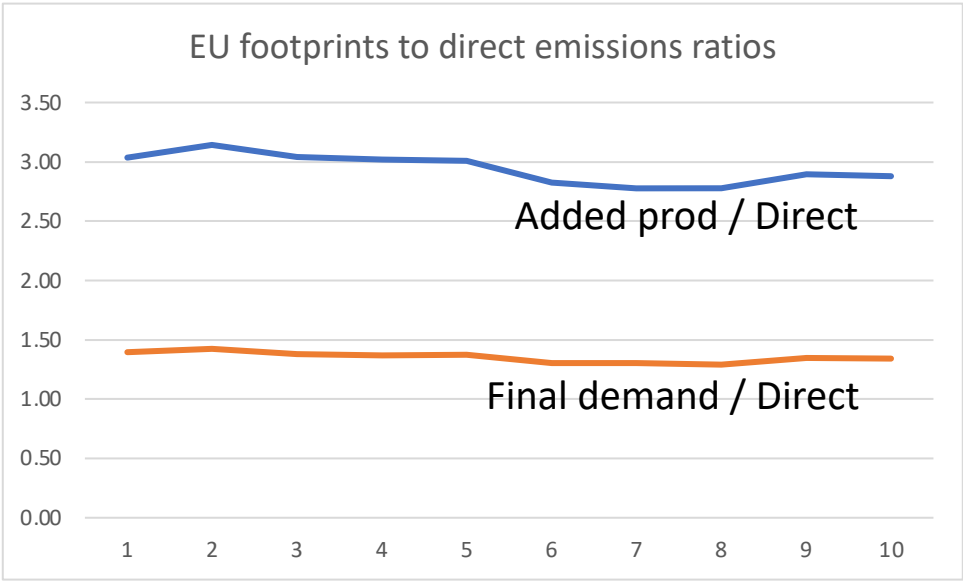
Direct emissions	Final Consumption embedded emissions	Production embedded emissions	Usage/disposal emissions
Only one step in value the chain	Full cradle to gate steps In the value chain	Full cradle to gate steps In the value chain	Full gate to grave steps In the value chain
Scope 1	Upstream Scope 3 of final users	Upstream Scope 3 + Scope 1&2	Downstream Scope 3
National Statistics reported to UN and verified	Classical Input-Ouput (IO) analysis (Leontief 1970)	Can be estimated by IOA (also done by LCA)	Requires LCA
Adds up to global emissions of industry (by definition)	Also adds up to global emissions of industry (nice property)	Sum is much higher than global emissions of industry (strong overlaps)	Usage/disposal + Production embedded = full life cycle

Trajectories over the 2010-2019 decade

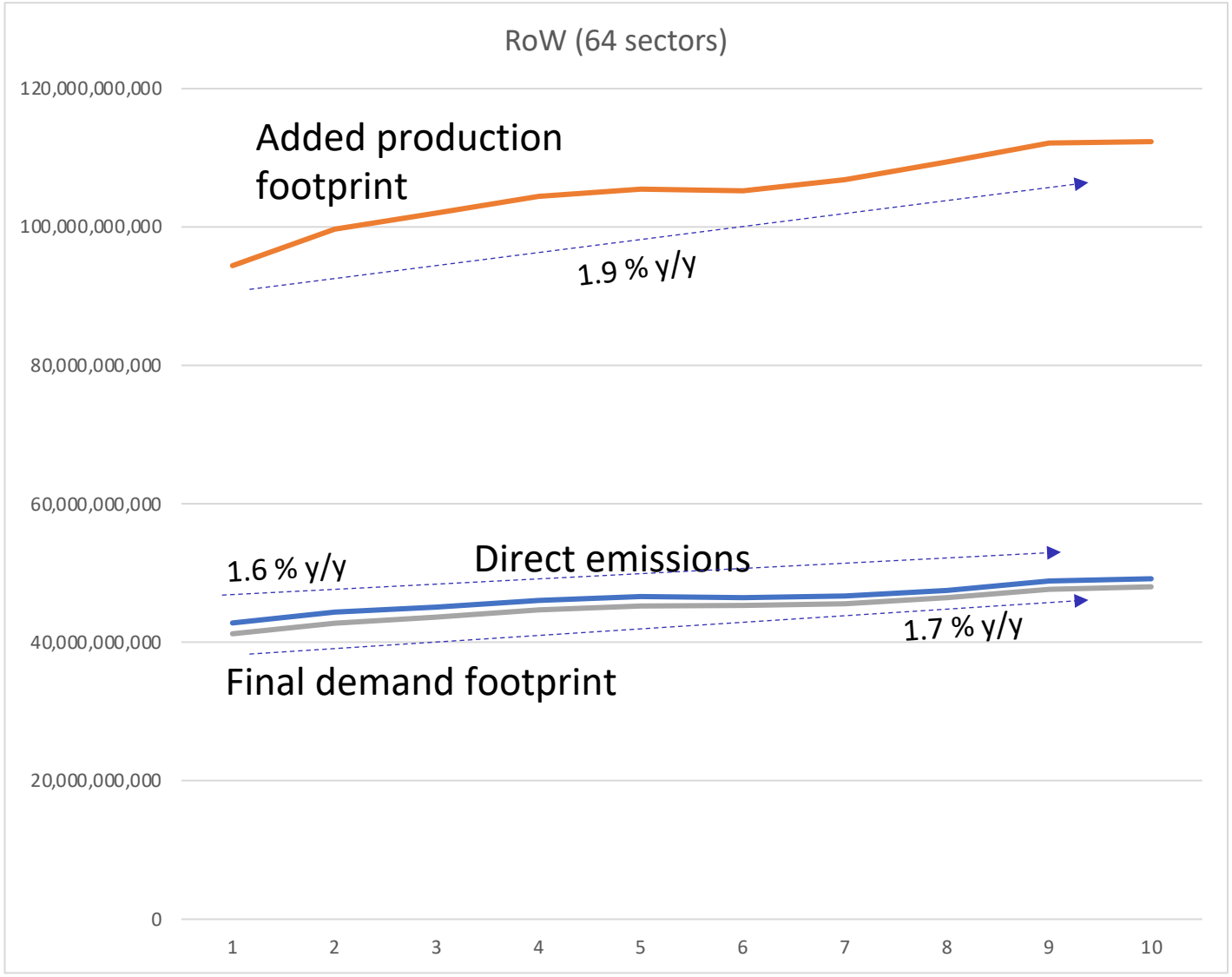
- Data:
  - Figaro MRIO table from EUROSTAT
  - Emissions data from EUROSTAT complemented by EDGAR
- Trajectories:
  - Europe and Rest of the World for all sectors
  - ICT sectors

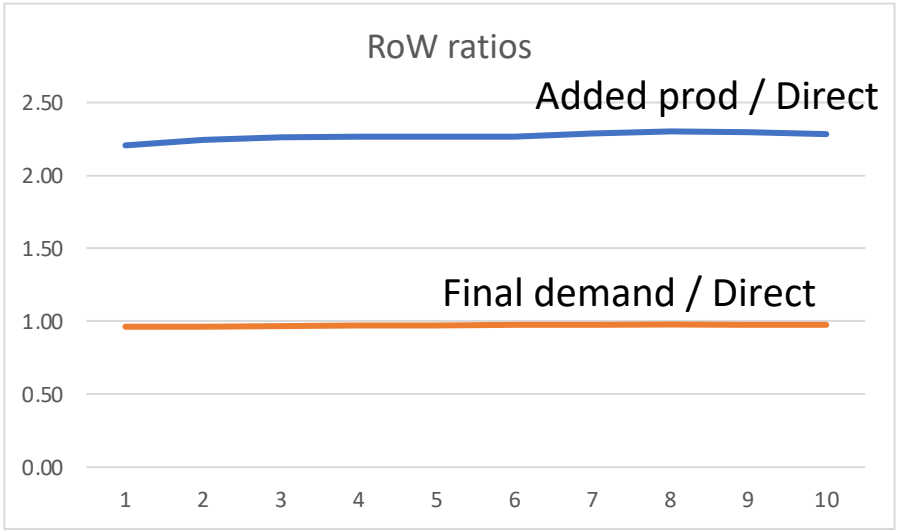
Global footprint pattern for Europe



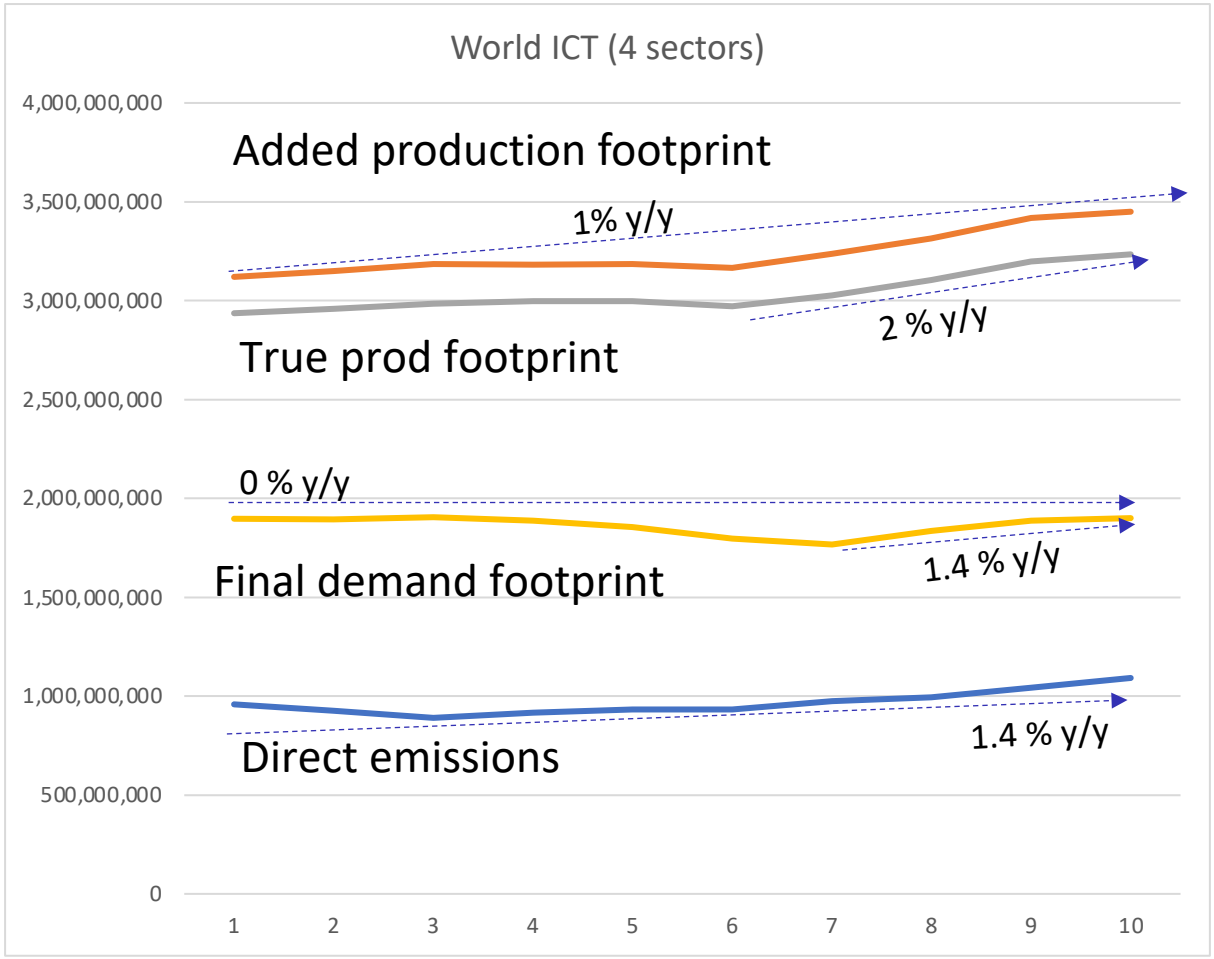


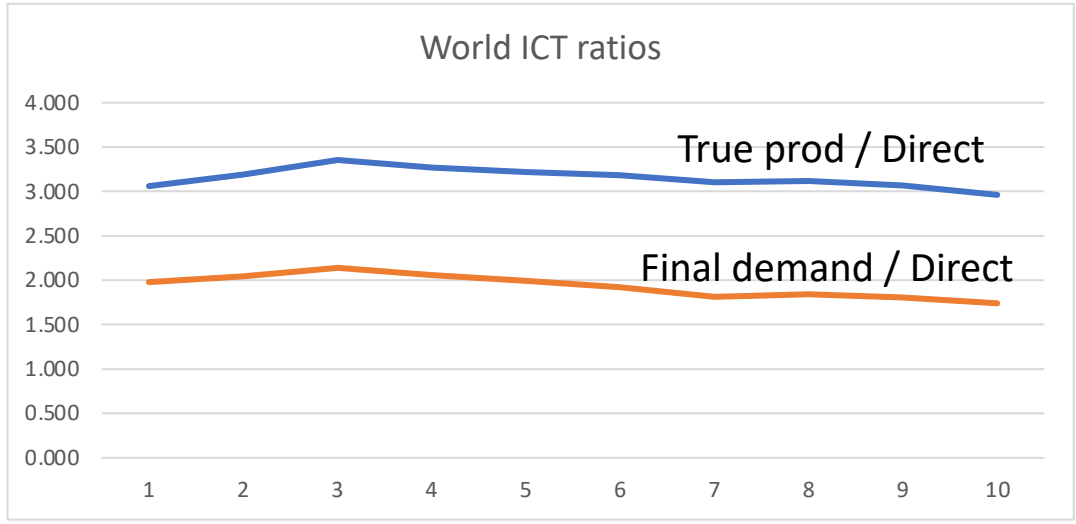
Global footprint pattern for Rest of World

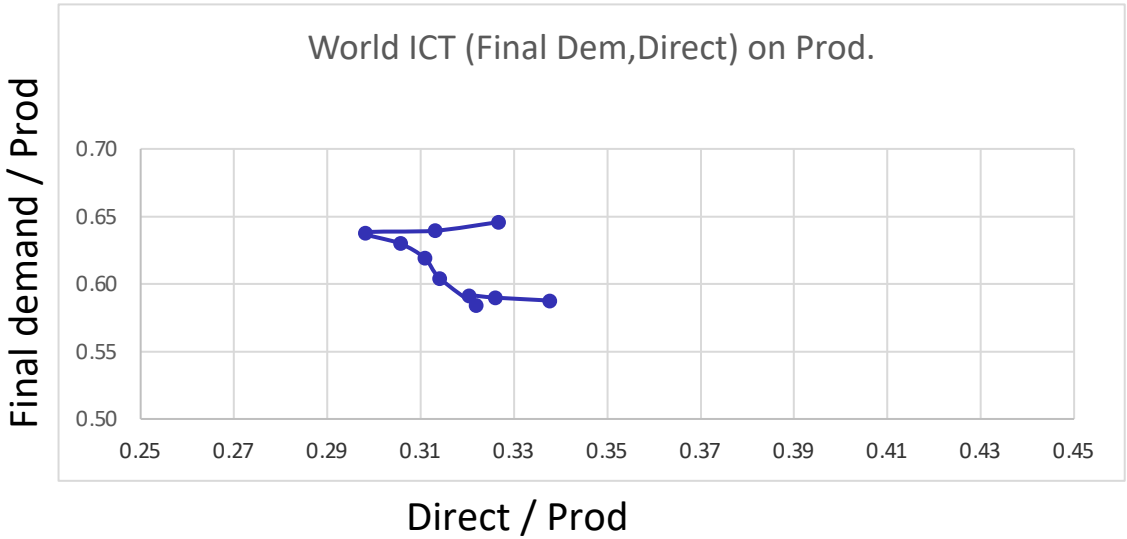




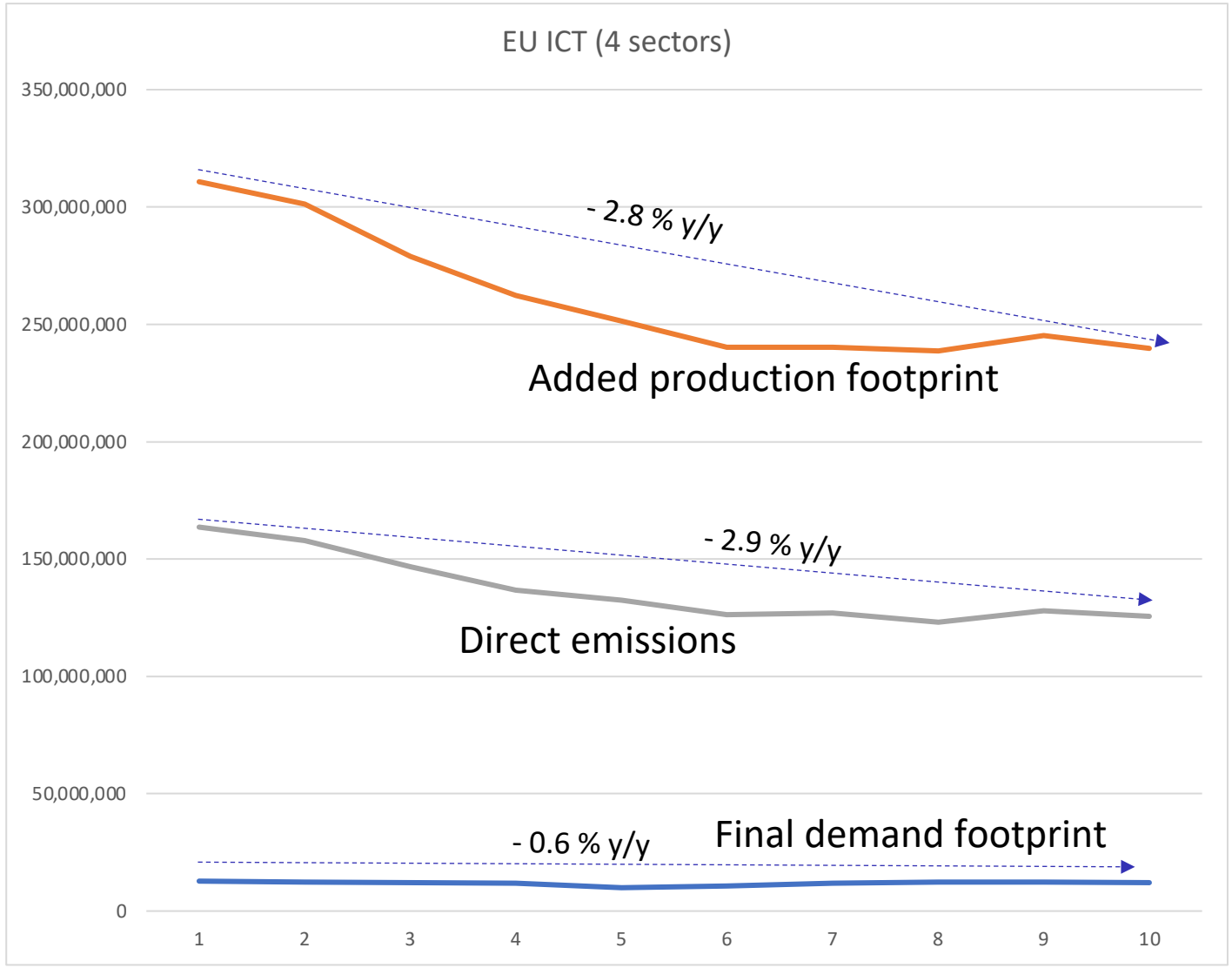
Footprint pattern for World ICT sectors

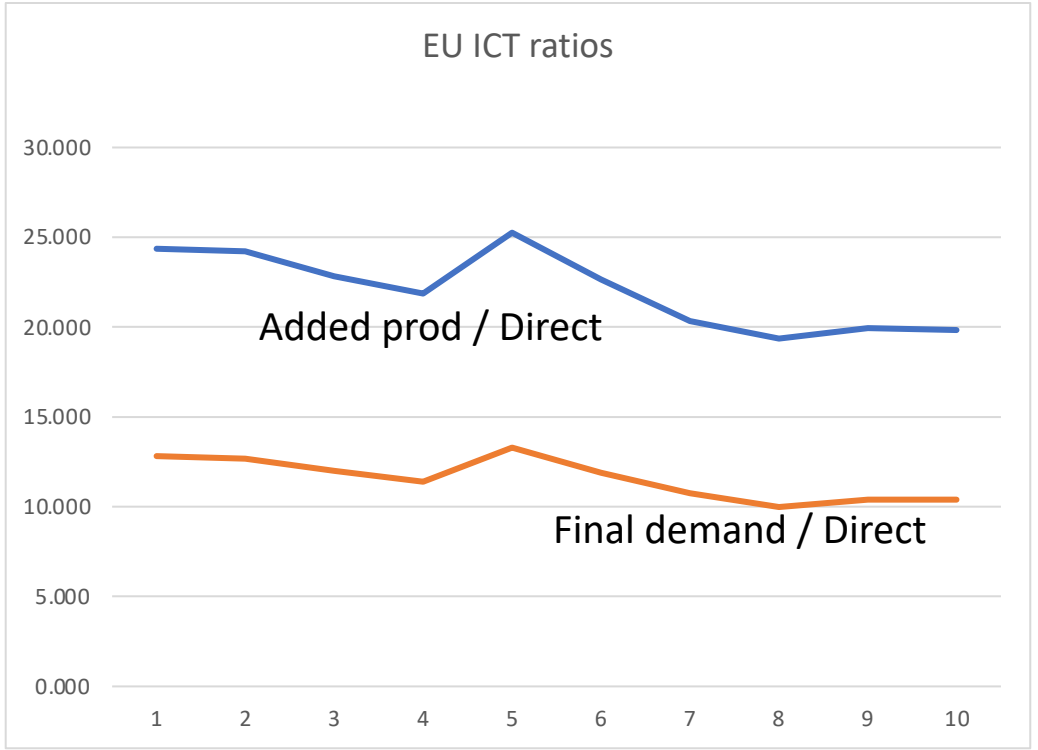




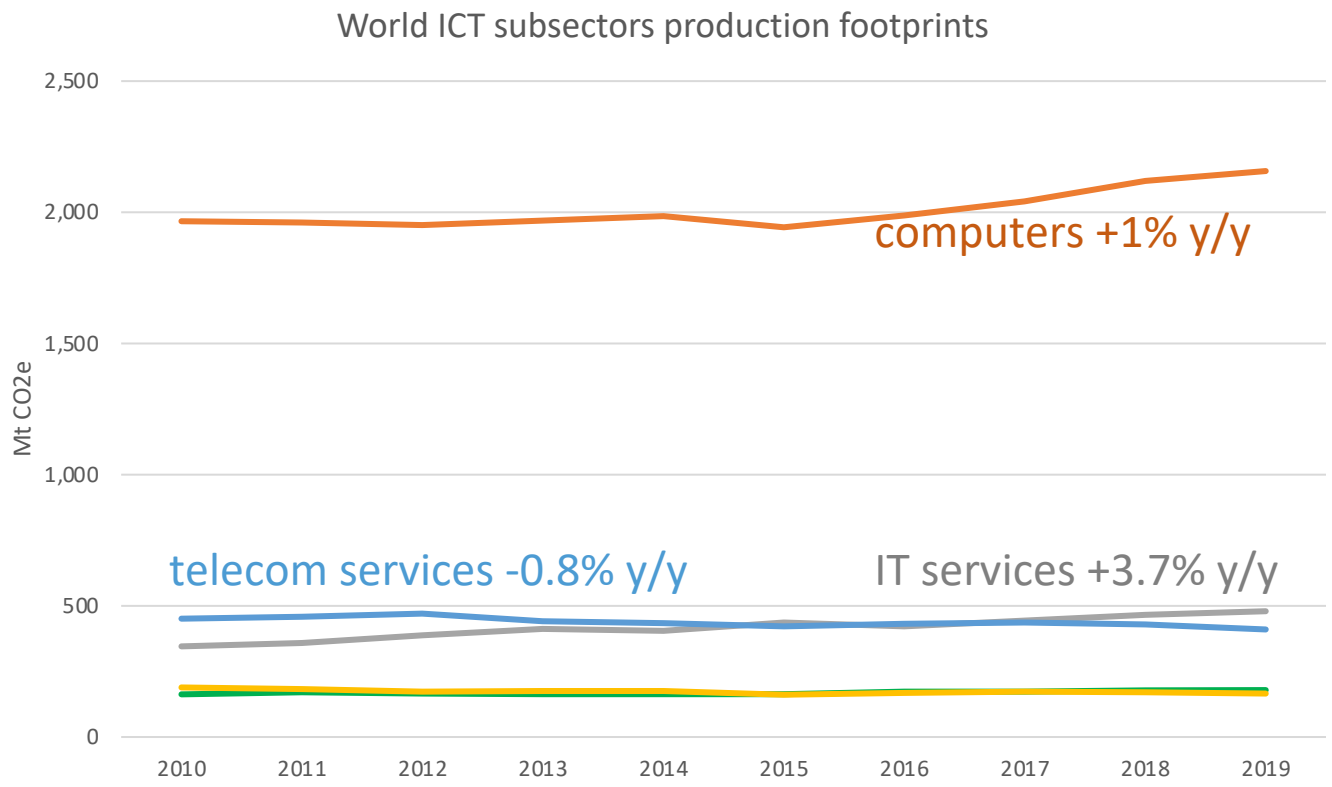


Footprint pattern for EU ICT sectors



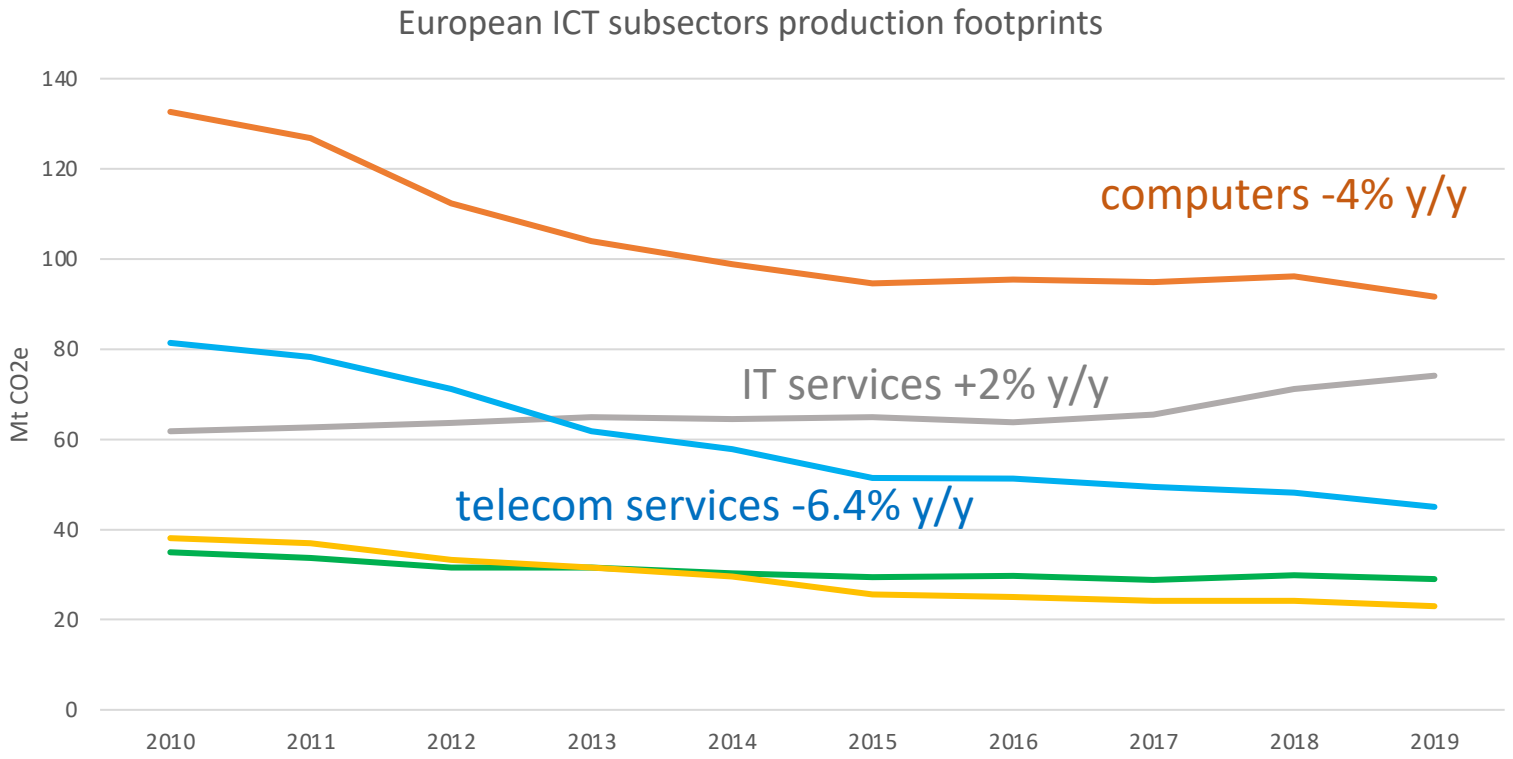


ICT breakdown prod footprint into subsectors



Production footprints of the five subsectors related to ICT (ICT subsectors): computers (orange), telecom (blue), IT services (grey), broadcast (green), publish (yellow). The subsectors have not been adjusted to compare to previous estimates of ICT footprint ("comparability adjustment").

ICT breakdown focuses on Europe



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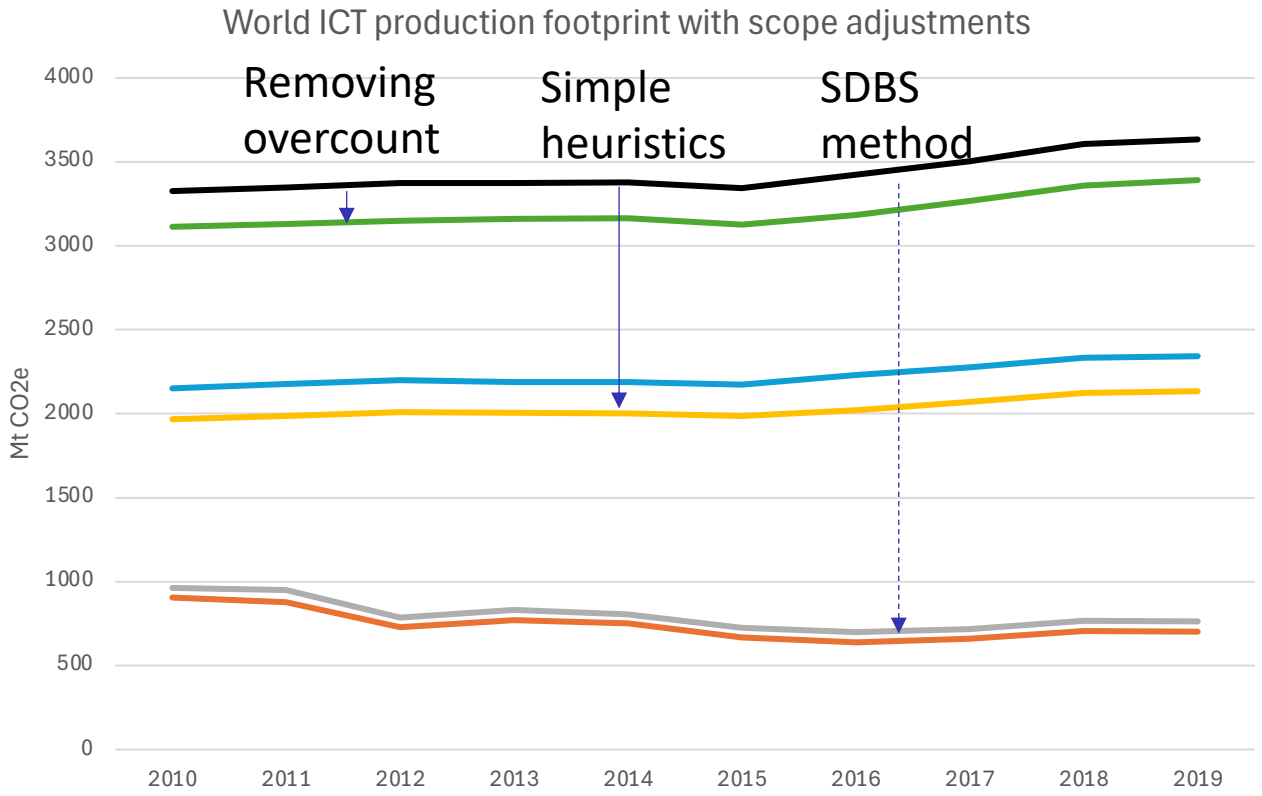
Adjusting scope to compare to reference studies



Production footprints of ICT: simple addition of the ICT subsectors (black), with fixed ratio adjustments (blue) and with dynamic SDBS evidence-based scope adjustments (grey) with SDBS evidence scope adjustments; true ICT footprints with simple addition error removed (green), with fixed ratio adjustments (yellow) and with dynamic SDBS evidence-based scope adjustments (orange) with SDBS evidence scope adjustments. The simple addition error adjustment is significantly smaller than the scope adjustments to increase comparability with the “reference ICT scope”.

Concluding remarks

- Preliminary results, to be further checked and analysed
- We need to check the quality of direct emissions data.
- Study trajectories at country level, including imports and exports

Appendix

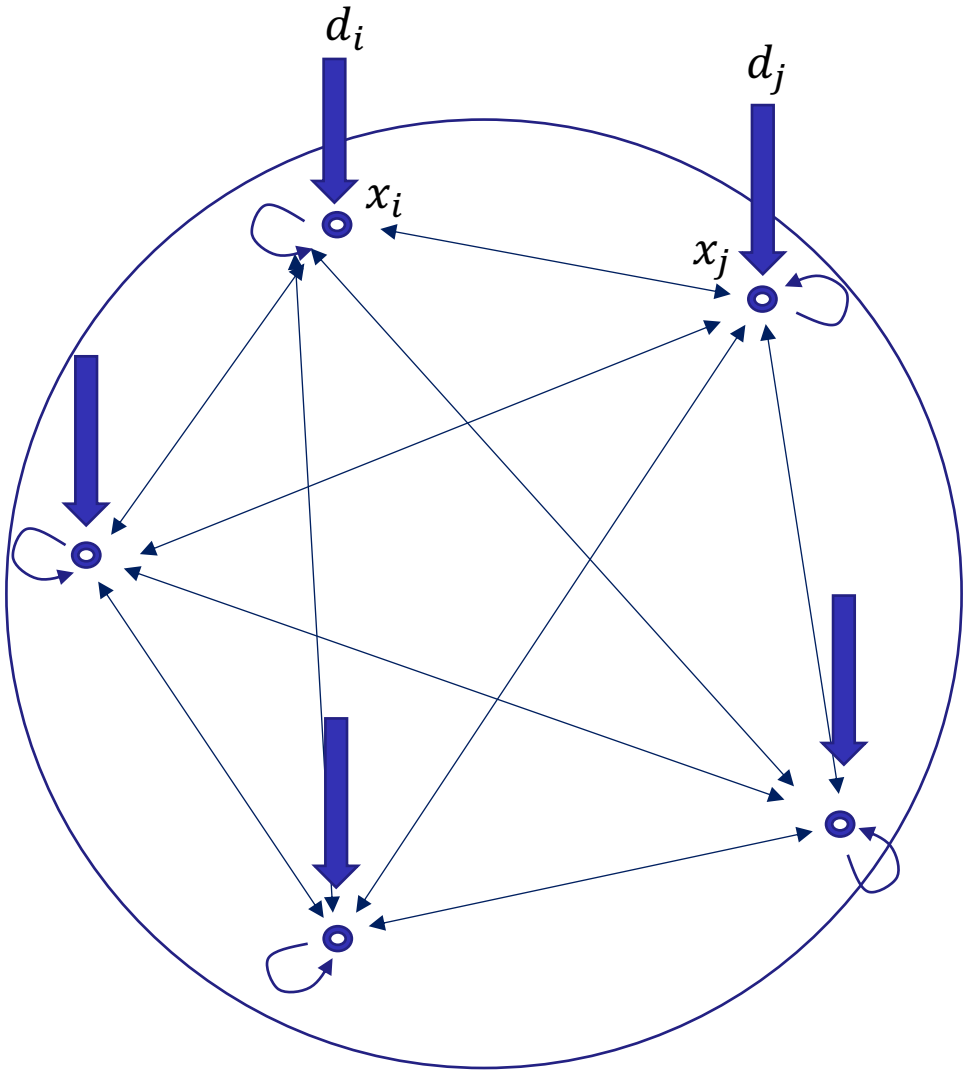
More methodological elements :

- Graphical interpretation
- A general model for different approaches
- Input-output tables of the economy
- Mathematical framework
- Classification of sectors

Other sectors' production footprint structures over the decade :

- Cradle activities
- Other sectors

Graph linear propagation



A general model for different approaches

- A directed graph (direction of the graph is the “stream” or the “flow”)
- It is collection of nodes i, j … involve asymmetrical linear interactions
- The state x_i of node i is equal to the addition of an external driver d_i plus positive linear function of its upstream nodes j including itself (self loop):

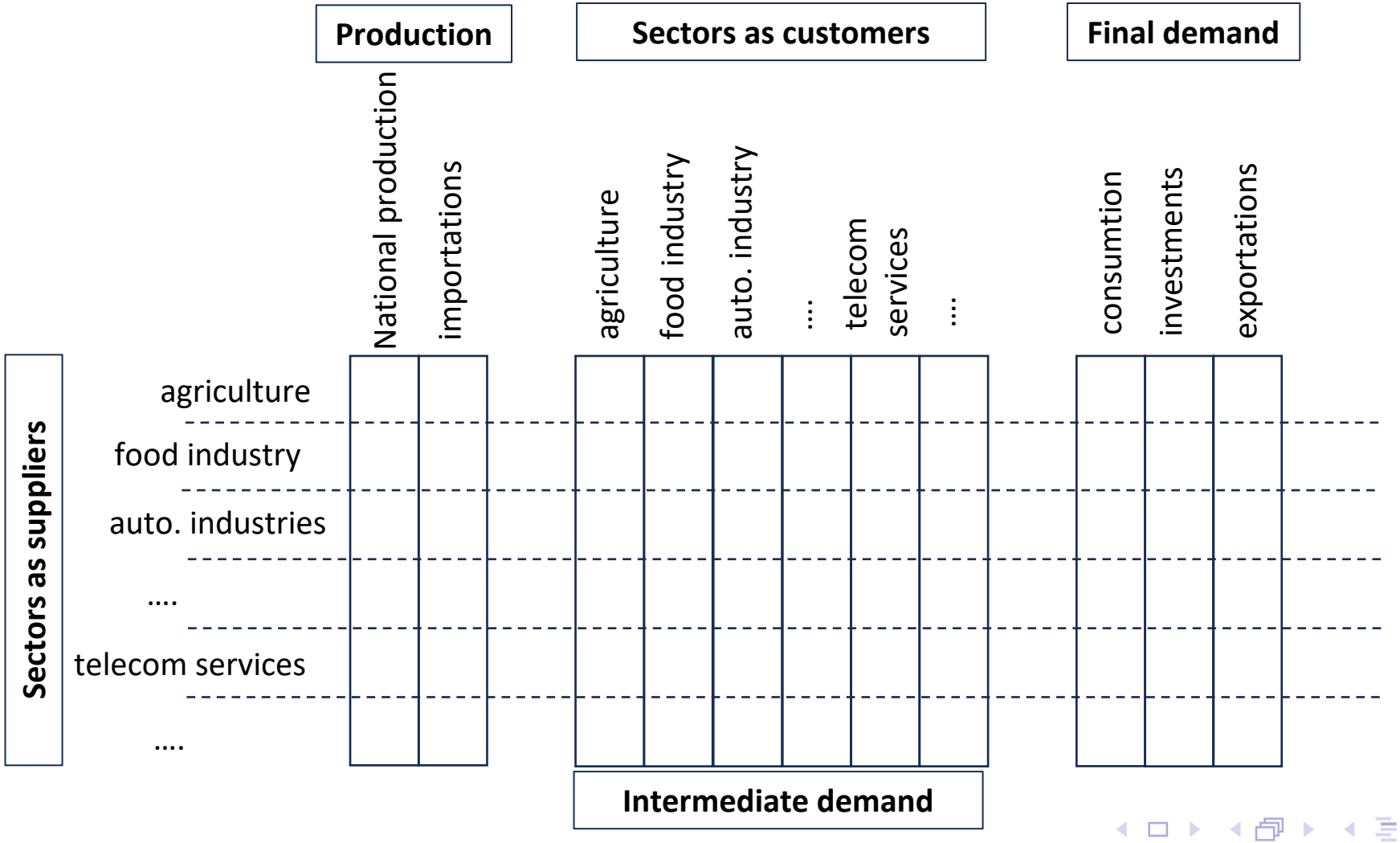
$$x_i = d_i + \sum a_{ij}\, x_j$$

- Matrix formulation: $(\boldsymbol{I} - \boldsymbol{A})\,.\,\boldsymbol{x} = \boldsymbol{d}$
- Systemic linear operator: $\boldsymbol{x} = \boldsymbol{f}(\boldsymbol{d}) = (\boldsymbol{I} - \boldsymbol{A})^{-1}\,.\,\boldsymbol{d}$

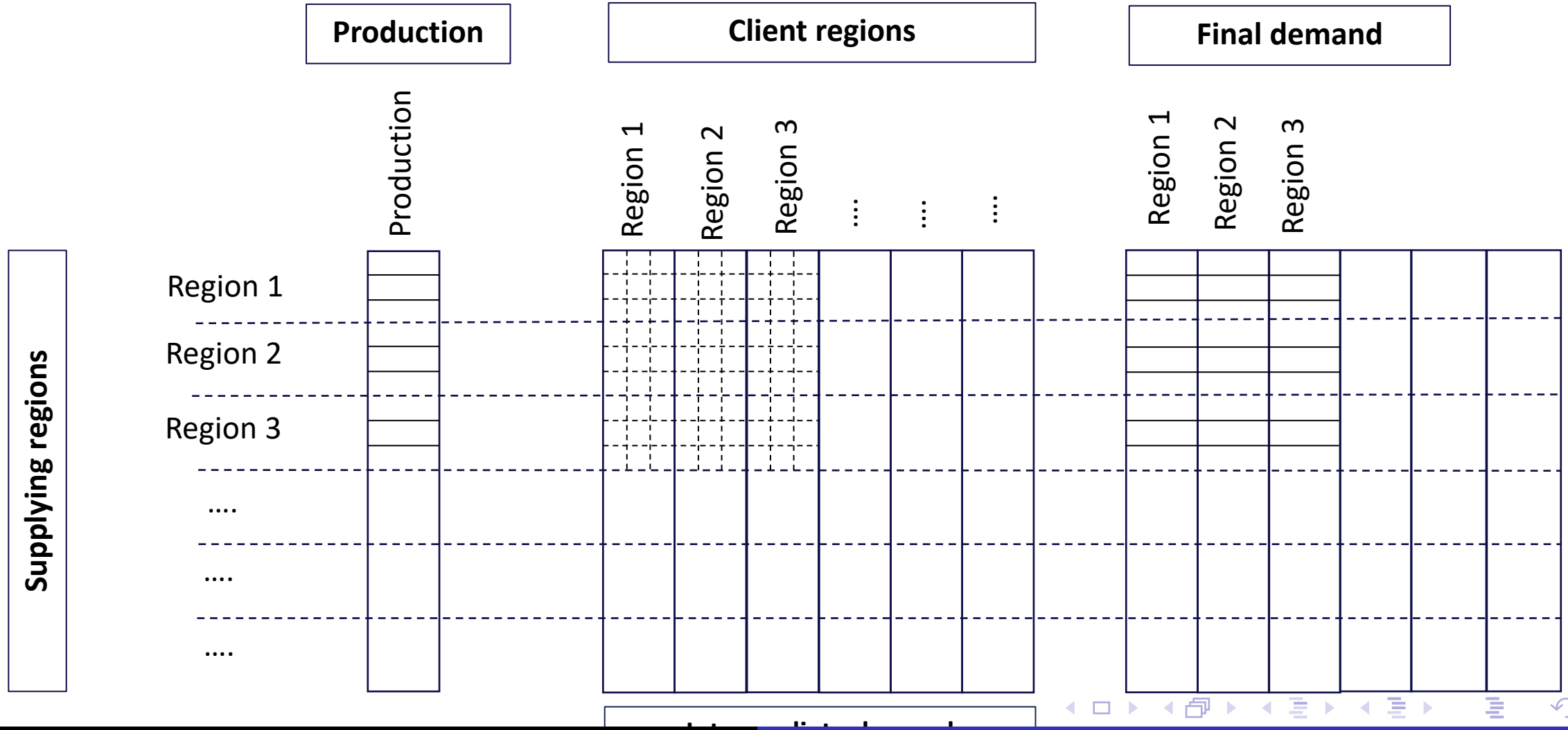
A common model for IOA and LCA

	Node	State x_i	Unit of x_i	Coefficient a_{ij}	Driver d_i
Leontief macroeconomic model (IOA)	Sector	Production of sector	Monetary	Input needed from suppliers per unit production	Final demand per sector
Upstream Life cycle model (LCA)	Technical process	Production of process	Physical	Input needed from supplying process per unit of product	Demand of analysed product
Downstream impact propagation (IOA)	Sector	Production embedded footprint	Impact volume (e.g. emissions)	Share of footprint passed to client using monetary or physical criterion	Direct impacts
			Impact intensity (monetary)		Direct impact intensities

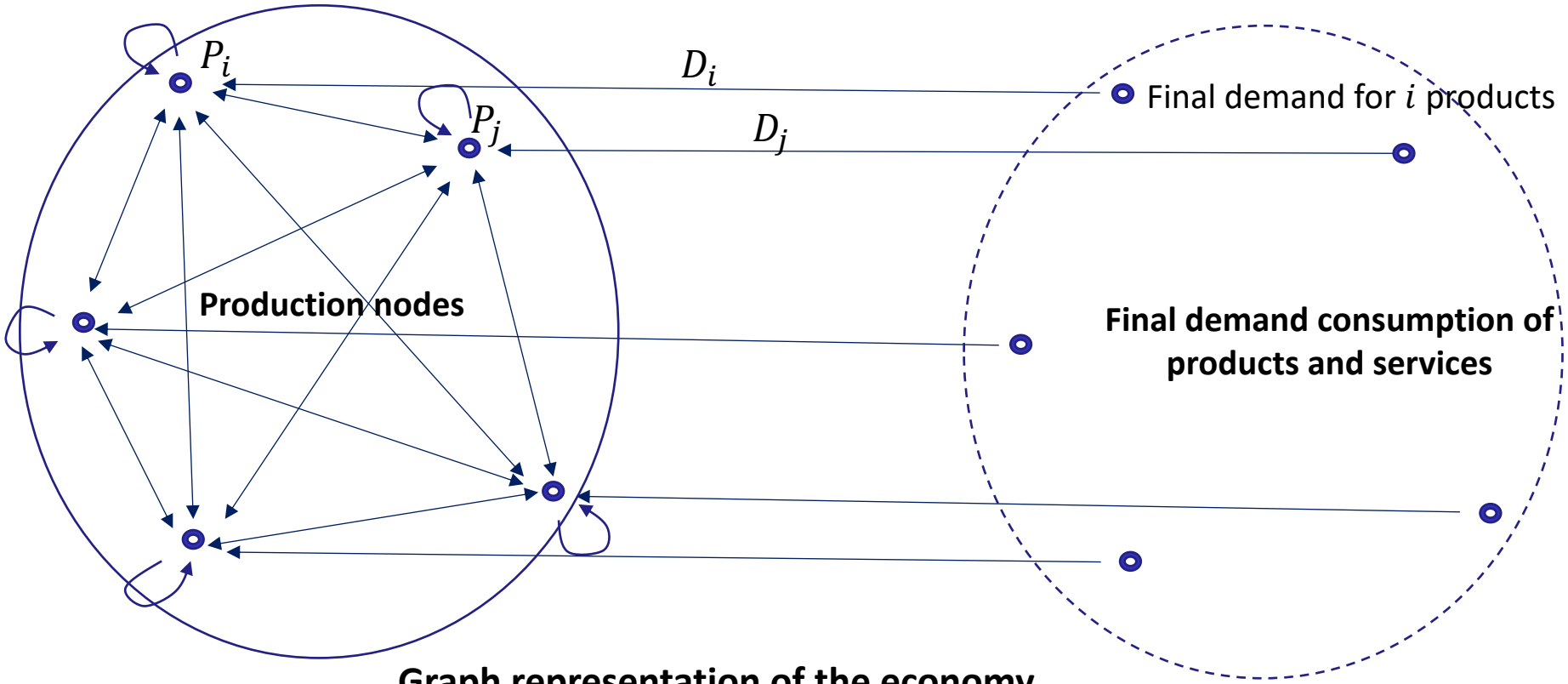
National level input-output matrices derive from years national accounts…



Multi Regional Input-Output (MRIO) accounts aggregate and extend years national accounts…



Using Leontief macroeconomic model



Graph representation of the economy

Role of final demand: *source nodes* sending supply requests D_i

Emissions derived from productions P_i using carbon intensities

Using Leontief macroeconomic model

1. Widely used to estimate the footprint of final demand consumption of product/services categories (*)

Final demand 2018 footprint of ICT ~ 1370 MtCO2

2. Can be used to estimate the production footprint of economic sectors (**)

Ratio production footprint / final demand footprint. given by:

$$\frac{1}{\mu_i}\frac{P_i}{D_i}$$

μ_i *: diagonal Leontief multiplicator in matrix* $(\boldsymbol{I} - \mathbf{A})^{-\mathbf{1}}$

3. Can be used to aggregate the production footprint of several sectors with no overcount (***)

Production 2018 footprint of ICT ~ 2190 MtCO2

(*) Handbook of input-output economics in industrial ecology, Sangwon Suh (Ed.), Springer 2010

(**) An Impact Inheritance Approach to the Estimation of the Carbon Footprints of Economic Activities, Charpentier, Conf. ICT4S 2022

(***) Estimating the Carbon Footprint of ICT Using Input-Output Analysis: Dealing with Overcounting and Other Challenges, Charpentier et al, Conf. ICT4S 2023

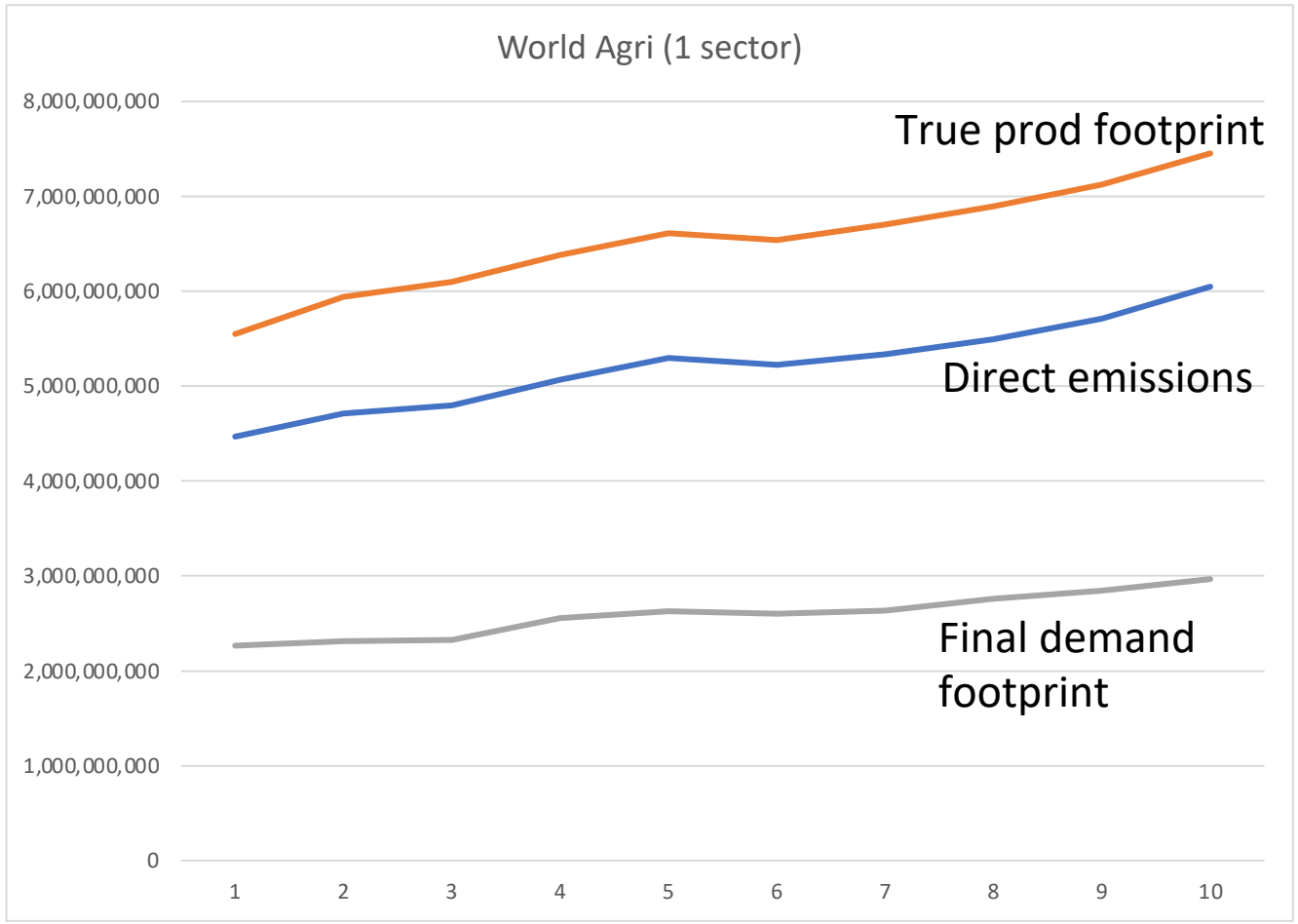
Typical macroeconomic breakdown into sectors (NACE 17 sectors)

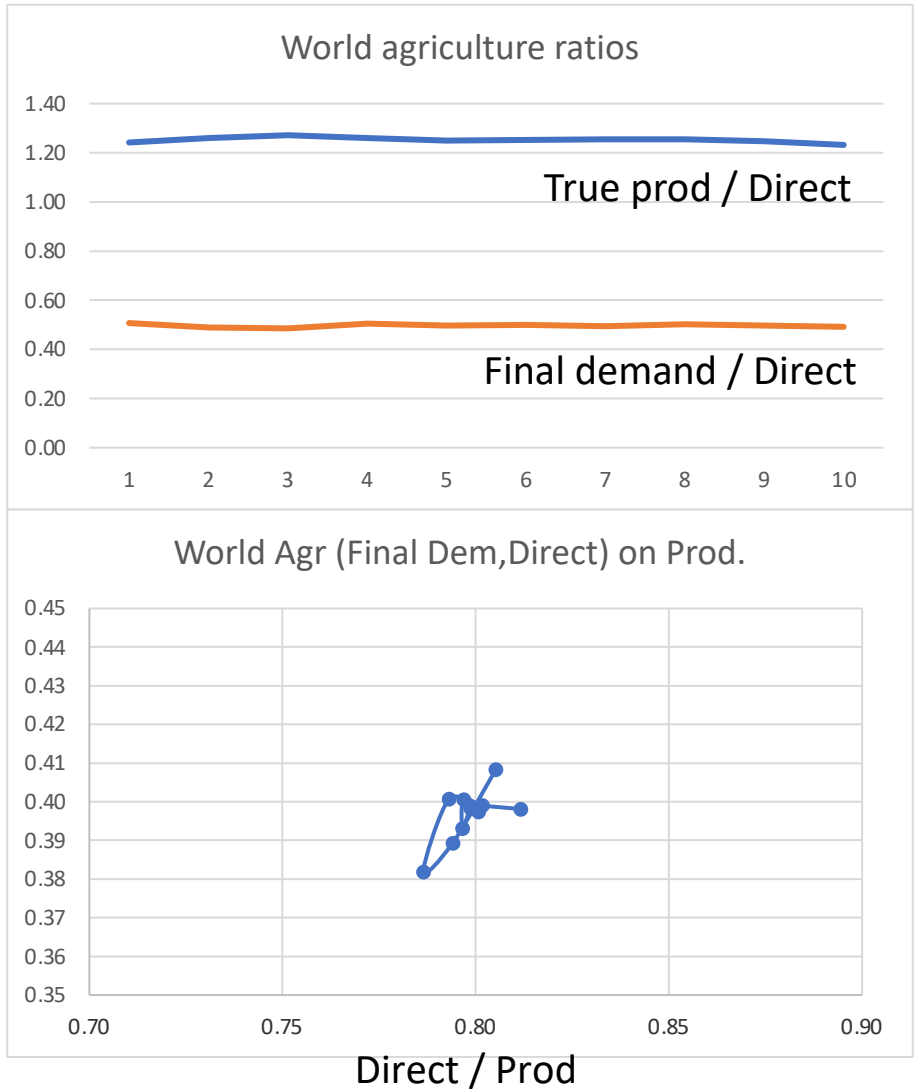
Short name	NACE sectors
Agriculture	Agriculture, forestry, fisheries
Energy	Raw materials extraction, energy, water, waste management, depollution
Food	Food products, beverages, tabacco
Refineries	Coking and refining plants
Electrical	Manufacturing electrical, electronic, computer equipment and machines
Vehicles	Manufacturing transport equipment
Other industries	Manufacturing other industrial products
Building	Building
Trade	Trade, repair of vehicles
Transportation services	Transportation and storage
Hotel	Accomodation and catering services
Info.communication	Information and communication services
Financial	Financial services and insurance
Real estate	Real estate
Advanced services	Special activities, scientific and technical activities. Administrative and support.
Government	Public services, education, healthcare, social services.
Other services	Other services

Figaro sector classification (NACE 64)

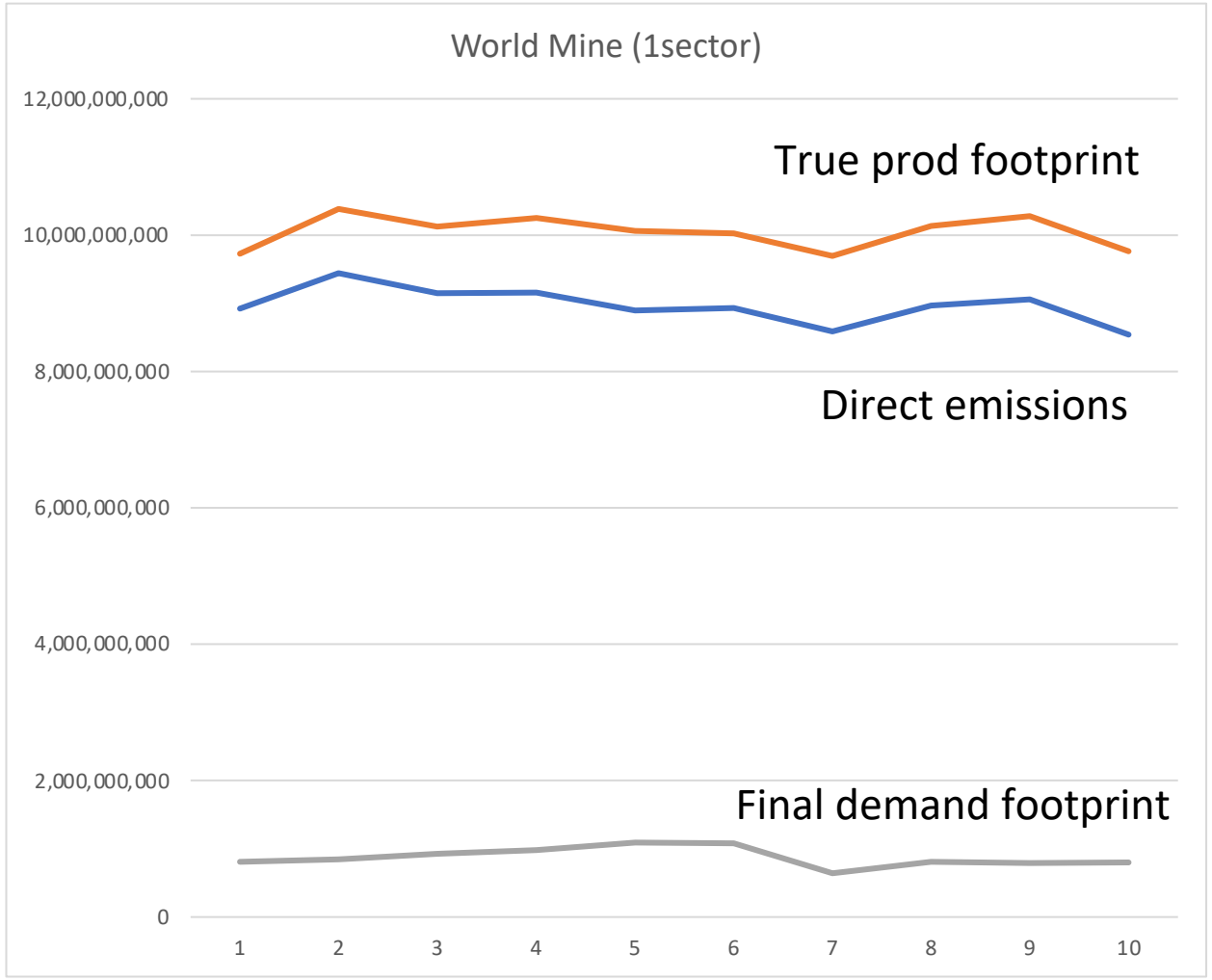
Crop and animal production, hunting and related service activities	Forestry and logging	Fishing and aquaculture	Mining and quarrying	Manufacture of food products; beverages and tobacco products	Manufacture of textiles, wearing apparel, leather and related products
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Manufacture of paper and paper products	Printing and reproduction of recorded media	Manufacture of coke and refined petroleum products	Manufacture of chemicals and chemical products	Manufacture of basic pharmaceutical products and pharmaceutical preparations
Manufacture of rubber and plastic products	Manufacture of other non-metallic mineral products	Manufacture of basic metals	Manufacture of fabricated metal products, except machinery and equipment	Manufacture of computer, electronic and optical products	Manufacture of electrical equipment
Manufacture of machinery and equipment n.e.c.	Manufacture of motor vehicles, trailers and semi-trailers	Manufacture of other transport equipment	Manufacture of furniture; other manufacturing	Repair and installation of machinery and equipment	Electricity, gas, steam and air conditioning supply
Water collection, treatment and supply	Sewerage, waste management, remediation activities	Construction	Wholesale and retail trade and repair of motor vehicles and motorcycles	Wholesale trade, except of motor vehicles and motorcycles	Retail trade, except of motor vehicles and motorcycles
Land transport and transport via pipelines	Water transport	Air transport	Warehousing and support activities for transportation	Postal and courier activities	Accommodation and food service activities
Publishing activities	Motion picture, video, television programme production; programming and broadcasting activities	Telecommunications	Computer programming, consultancy, and information service activities	Financial service activities, except insurance and pension funding	Insurance, reinsurance and pension funding, except compulsory social security
Activities auxiliary to financial services and insurance activities	Real estate activities	Legal and accounting activities; activities of head offices; management consultancy activities	Architectural and engineering activities; technical testing and analysis	Scientific research and development	Advertising and market research
Other professional, scientific and technical activities; veterinary activities	Rental and leasing activities	Employment activities	Travel agency, tour operator reservation service and related activities	Security and investigation, service and landscape, office administrative and support activities	Public administration and defence; compulsory social security
Education	Human health activities	Residential care activities and social work activities without accommodation	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	Sports activities and amusement and recreation activities	Activities of membership organisations
Repair of computers and personal and household goods	Other personal service activities	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	Activities of extraterritorial organisations and bodies		

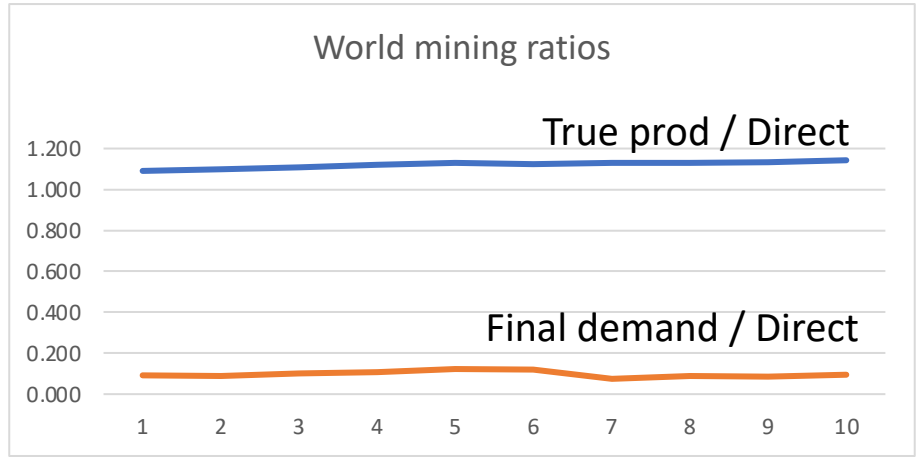
Footprint pattern for World agriculture sector

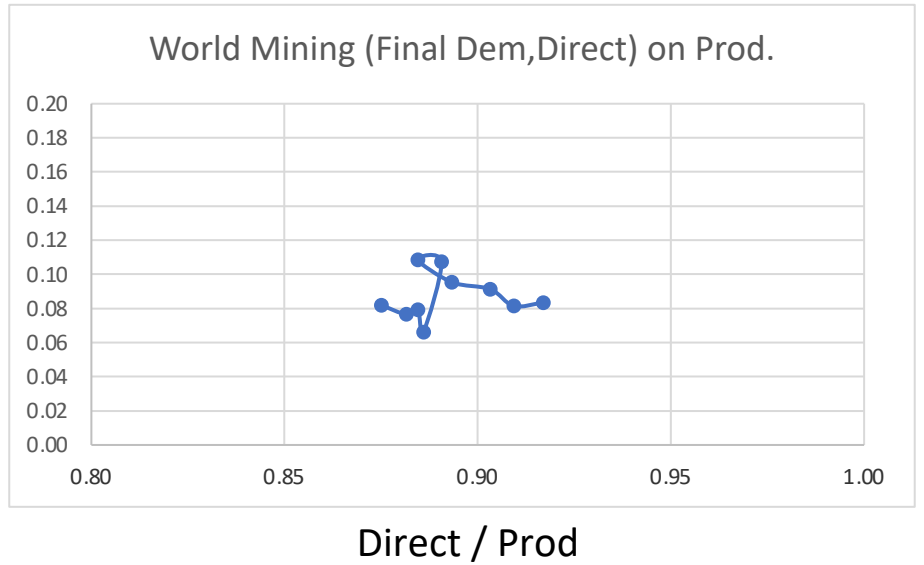




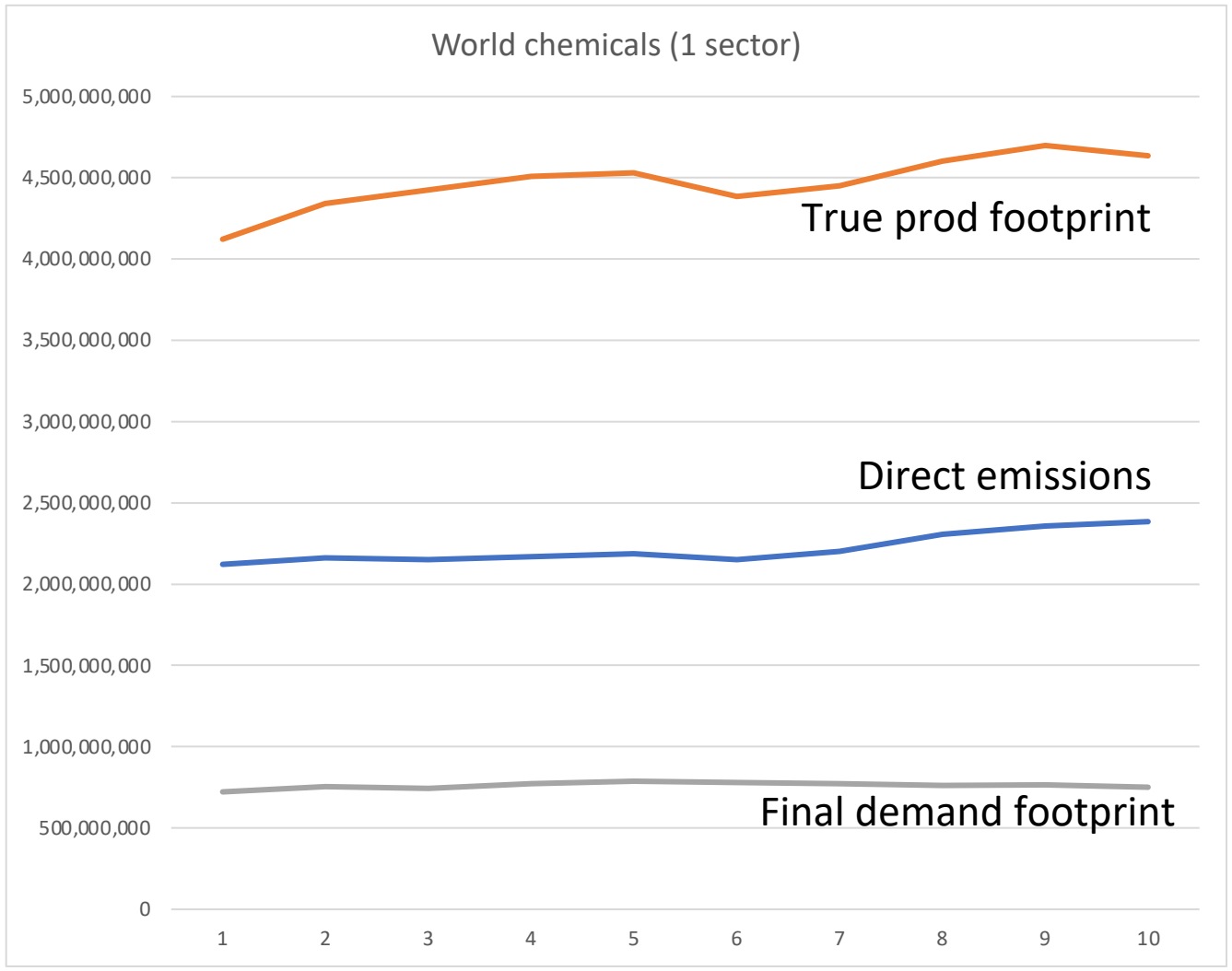
Footprint pattern for World mining sector

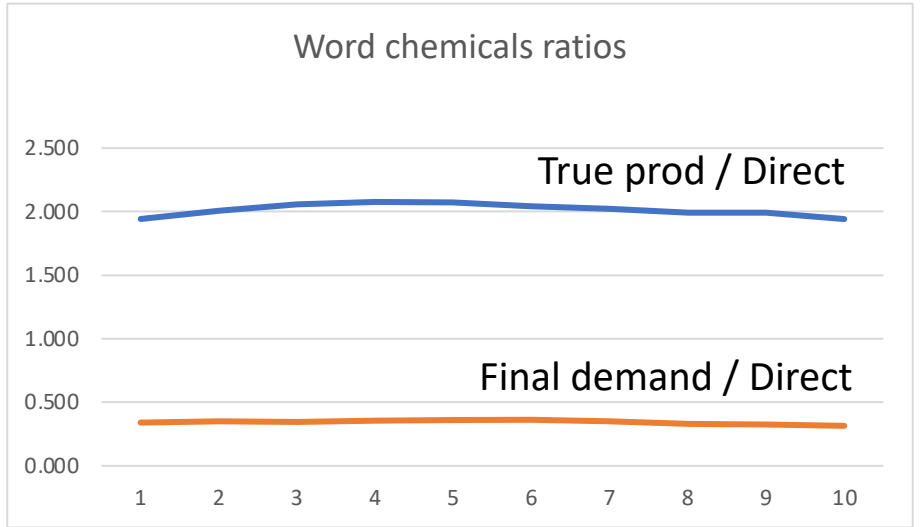


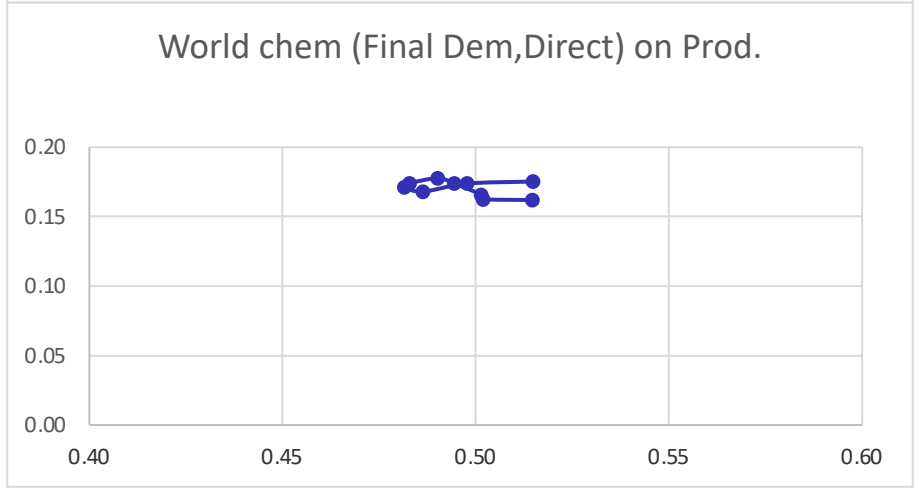




Footprint pattern for World Chemicals sector







Footprint pattern for World land transportations sector