Incorporating FAO trade and production database to estimate supply chain location information for agricultural products

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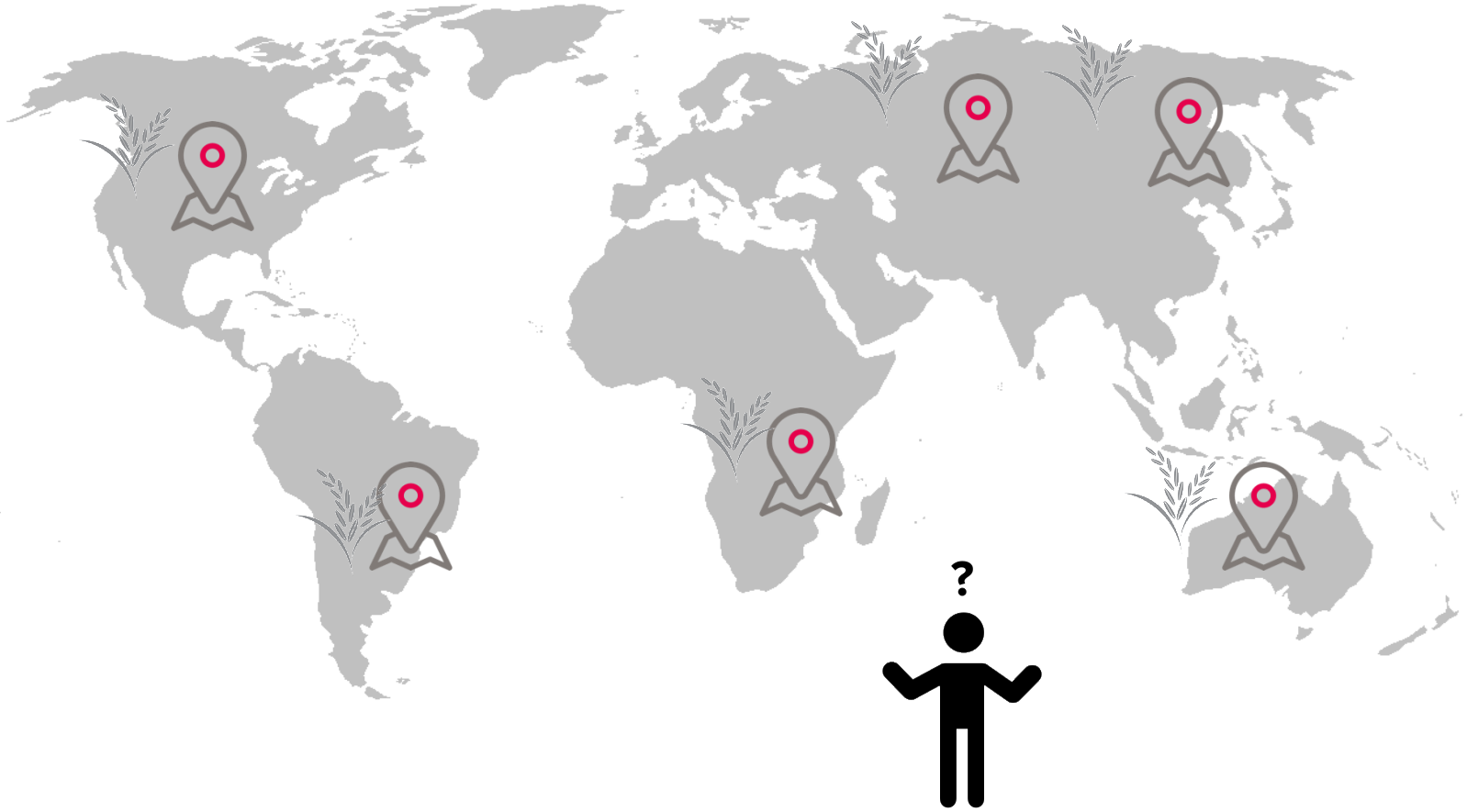
Quantis

GIVEN: 1 kg of soybeans are purchased/consumed/exported from a region.
UNKNOWN: Where are the soybeans sourced from?



GIVEN: 1 kg of soybeans is produced from a region.
UNKNOWN: Where are the soybeans being distributed across regions?

LOCATION MATTERS

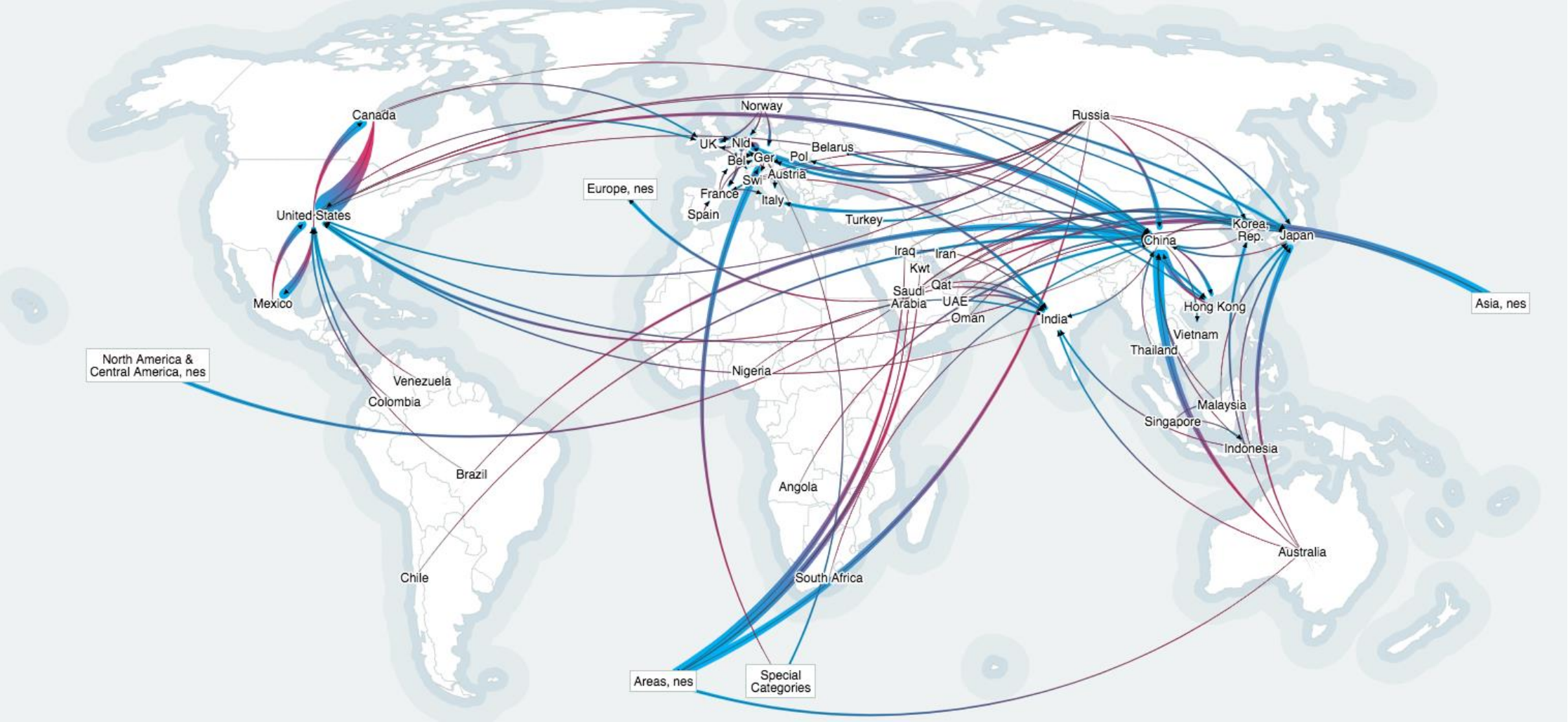
Improve precision to

- ✓ Set corporate Science Based Targets
- ✓ Calculate corporate footprint
- ✓ Measure product footprint

Utilize regionalized LCI data set and LCIA factors

Identify hotspot and risks along the supply chain

Production and Trade flow (bilateral import and export) data are available from both FAOSTAT (physical trade flow) and MRIO database (sector-aggregated monetary flow)



Source: https://resourcetrade.earth/

Case study: a potential trade situation from FAOSTAT database

Unit	Production **p** [tons]	Bilateral trade data **Z** [tons]				Total imports [tons]	Environmental impact per unit [ha/ton]
			A	B	C	D	
Country A	200		0	0	100	200	*300*	1/6
Country B	1000		0	0	0	0	*0*	1/3
Country C	100		50	350	0	50	*450*	1/9
Country D	10		50	200	200	0	*450*	1/12
	1310	Total exports	*100*	*550*	*300*	*250*		

Country B has high land use intensity per kg of soybean

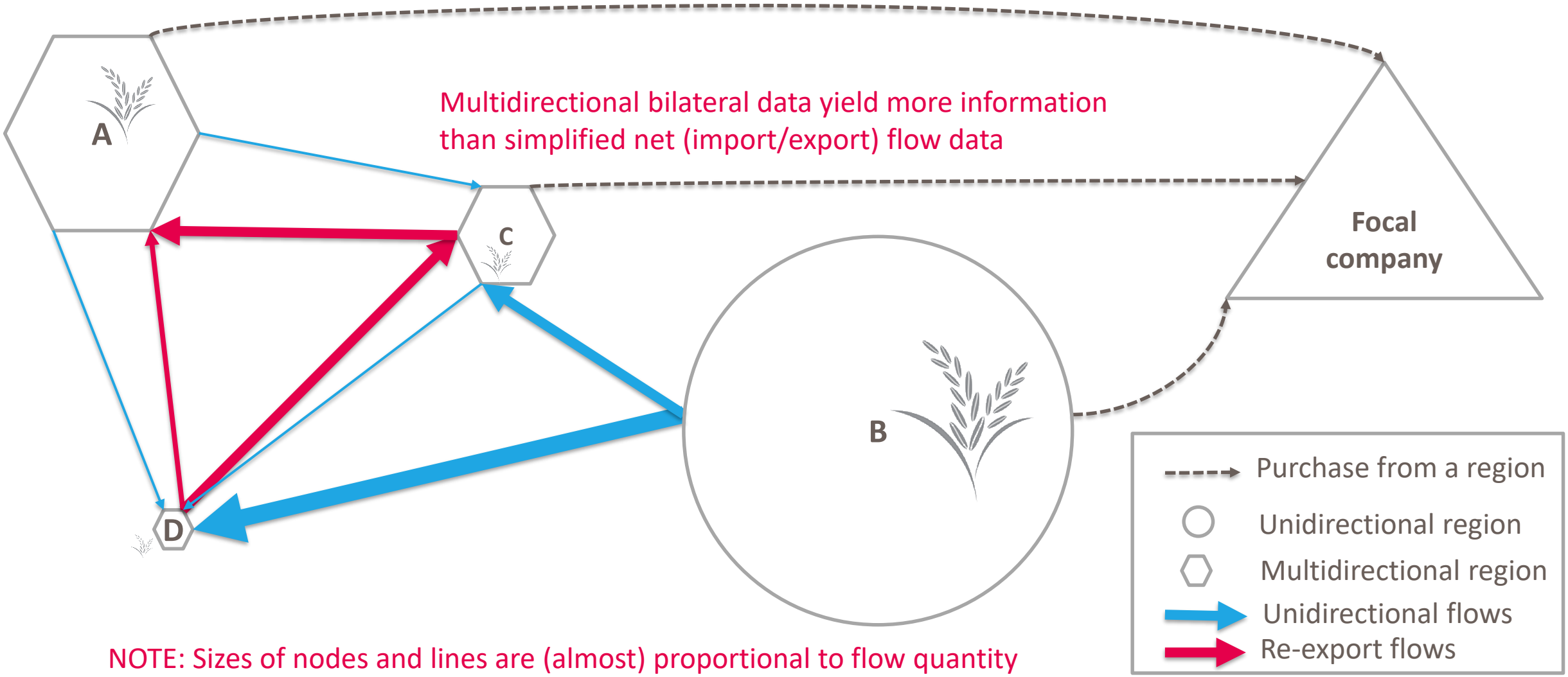
Country D has very low land use intensity per kg of soybean

Data source:
Kastner et al (2011)

$$x = p + Z = c + E$$

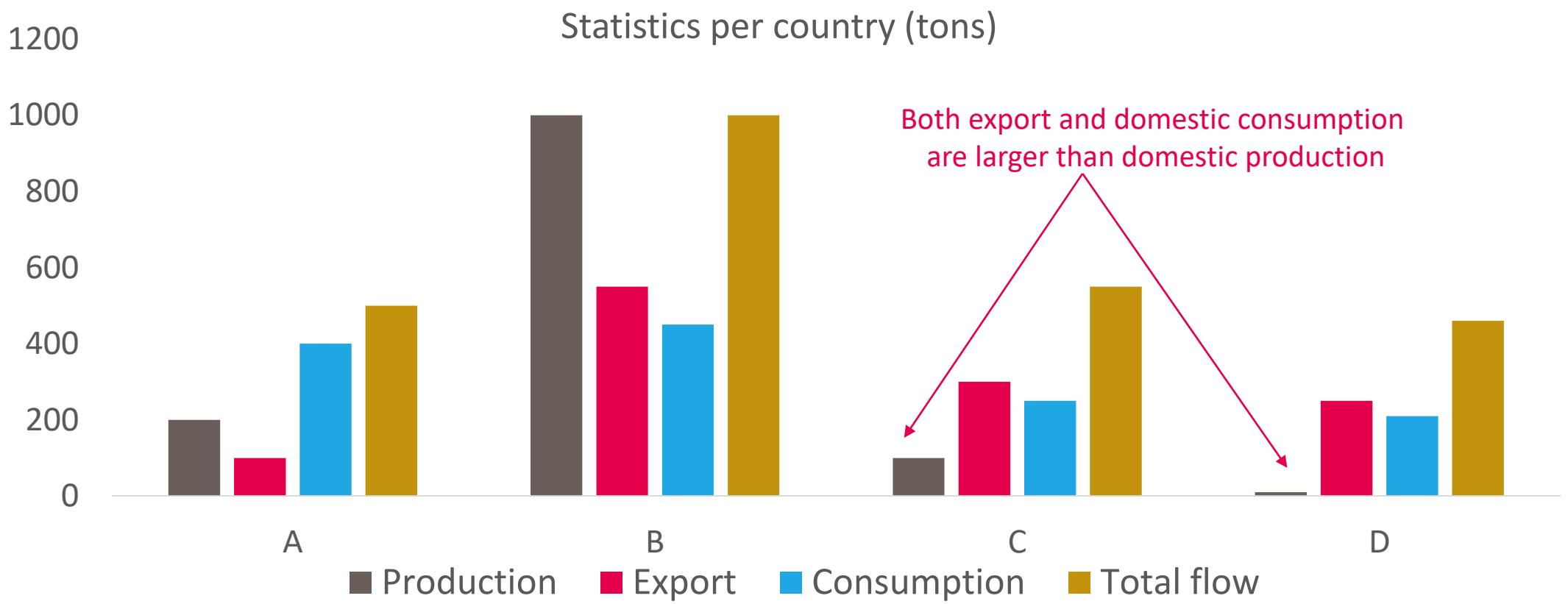
x is the total consumption flow for a given country node. It equals to the sum of domestic production (p) + gross import (Z), as well as the sum of domestic consumption (c) and gross export (E)

Multidirectional regional trading activities create network supply chain structure



NOTE: Sizes of nodes and lines are (almost) proportional to flow quantity

Production (node) capacity or trading (link) constraints are often ignored in LCA models!



A generic mathematic formulation of the problem in question

By consuming 1 kg in region 1, how many come from region 1's domestic production (r11), and importing from region 2 (r12), region 3 (r13) , and region 4 (r14), respectively? This can be formulated as a generic require matrix shown below:

$$R = \begin{bmatrix} r11 & \cdots & r14 \\ \vdots & & \vdots \\ & rij & \\ r31 & & r34 \\ r41 & \cdots & r44 \end{bmatrix}$$

Approaches and major assumptions

Method		Tiers of suppliers		Export composition assumption		FU basis	
Approach (most discussed)	Model specification	Tier 1	All tiers	Domestic	Total flow	Domestic Cons.*	Total flow*
Trade adjusted	• Trade adjusted				n.r		n.r
Tier 1 approach	• Tier-1		n.r				
Network approach (total flow)	• Leontief model • Ghosh model • Prod. & market	n.r		n.r		n.r.	

*domestic consumption= net import + domestic production, whereas total flow= gross import +domestic production

All roads lead to Rome!

- "Demand-driven" Leontief model (e.g. Kastner et al (2011) for soybean)

$$R = \hat{x}^{-1}(\mathrm{I} - Z\hat{x}^{-1})^{-1}\hat{p} = \begin{bmatrix} 0.44 & 0.48 & 0.08 & 0.01 \\ 0 & 1 & 0 & 0 \\ 0.05 & 0.75 & 0.20 & 0 \\ 0.07 & 0.81 & 0.09 & 0.02 \end{bmatrix}$$

- "Supply driven" Ghosh model (e.g. Qu, et al 2017 for electricity)

$$R = \mathrm{t}(\hat{x}^{-1}(\mathrm{I} - E\hat{x}^{-1})^{-1}\hat{p}) = \begin{bmatrix} 0.44 & 0.48 & 0.08 & 0.01 \\ 0 & 1 & 0 & 0 \\ 0.05 & 0.75 & 0.20 & 0 \\ 0.07 & 0.81 & 0.09 & 0.02 \end{bmatrix}$$

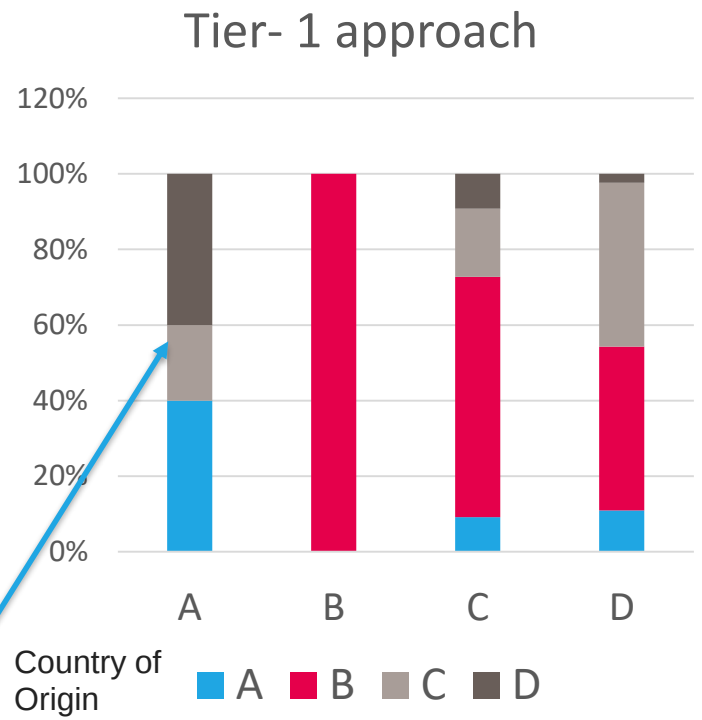
- Production activity and Market model

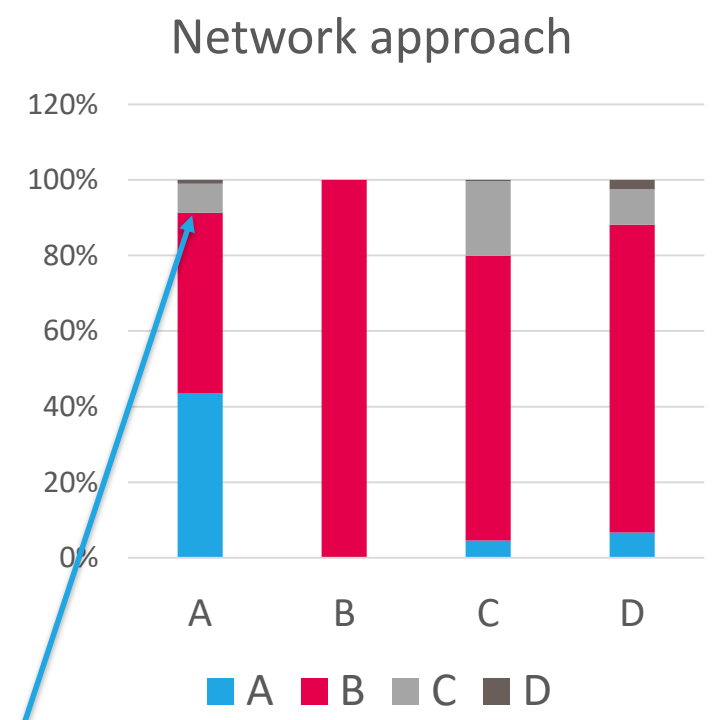
$$A^{-1} = \begin{bmatrix} I & t(R) \\ 0 & A' \end{bmatrix}$$

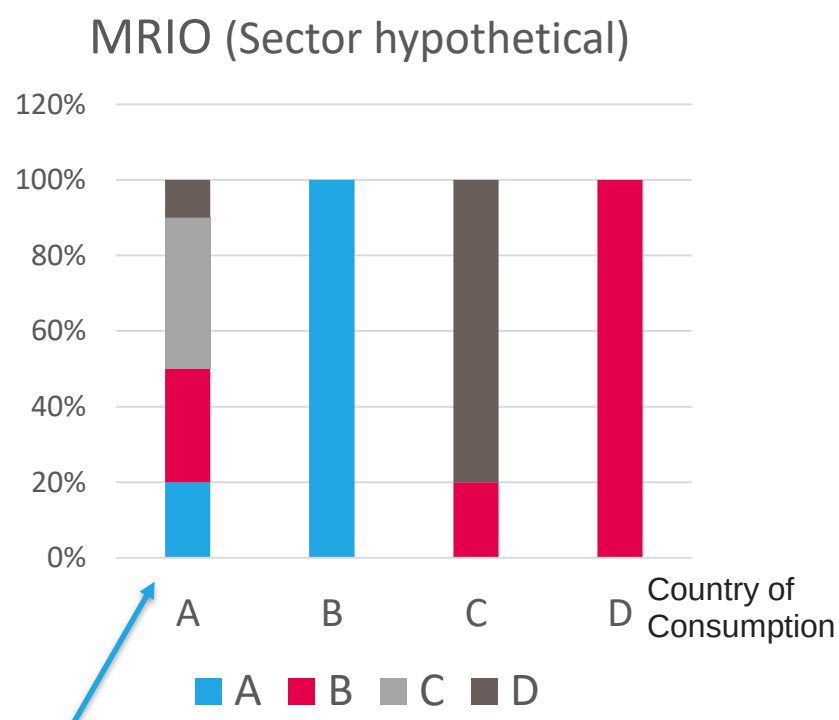
$$R = \begin{bmatrix} 0.44 & 0.48 & 0.08 & 0.01 \\ 0 & 1 & 0 & 0 \\ 0.05 & 0.75 & 0.20 & 0 \\ 0.07 & 0.81 & 0.09 & 0.02 \end{bmatrix}$$

With different modelling principles, all three network approaches generate equivalent results.

Comparing location sourcing countries:
Network approach likely provide best estimate





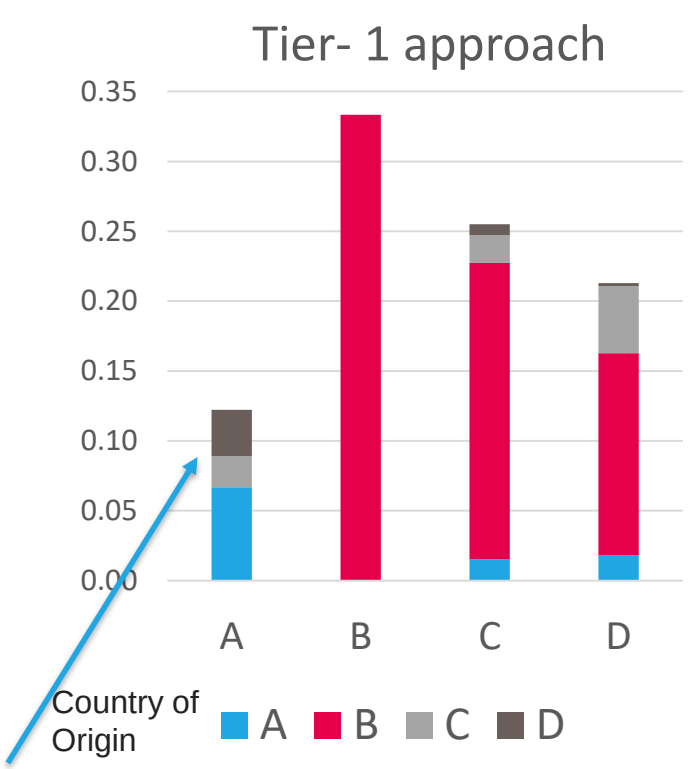


Do not make sense:
Country C and D export more than their productions

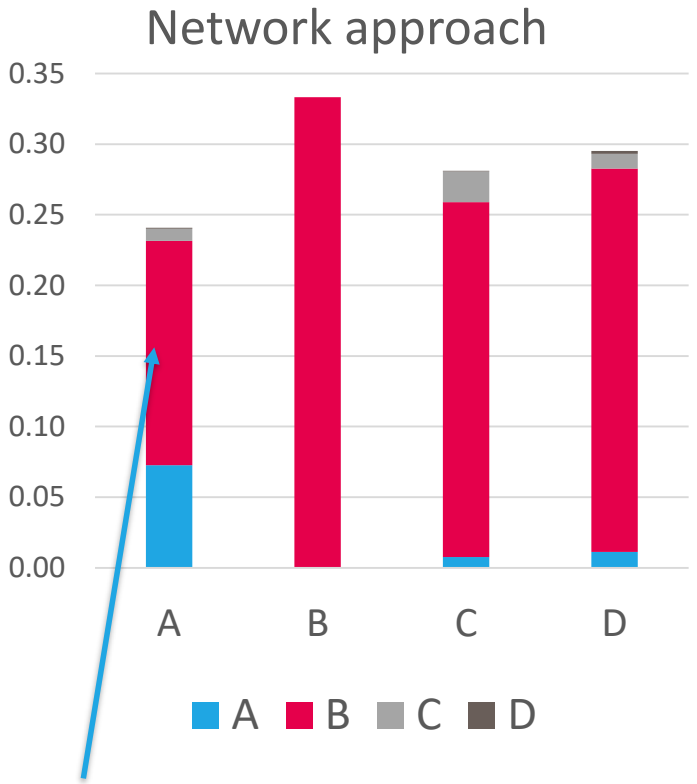
Country C and D import soybean from the largest producer country B, then Re-export to country A

It's no longer representing soybean anymore due to severe sector aggregation.

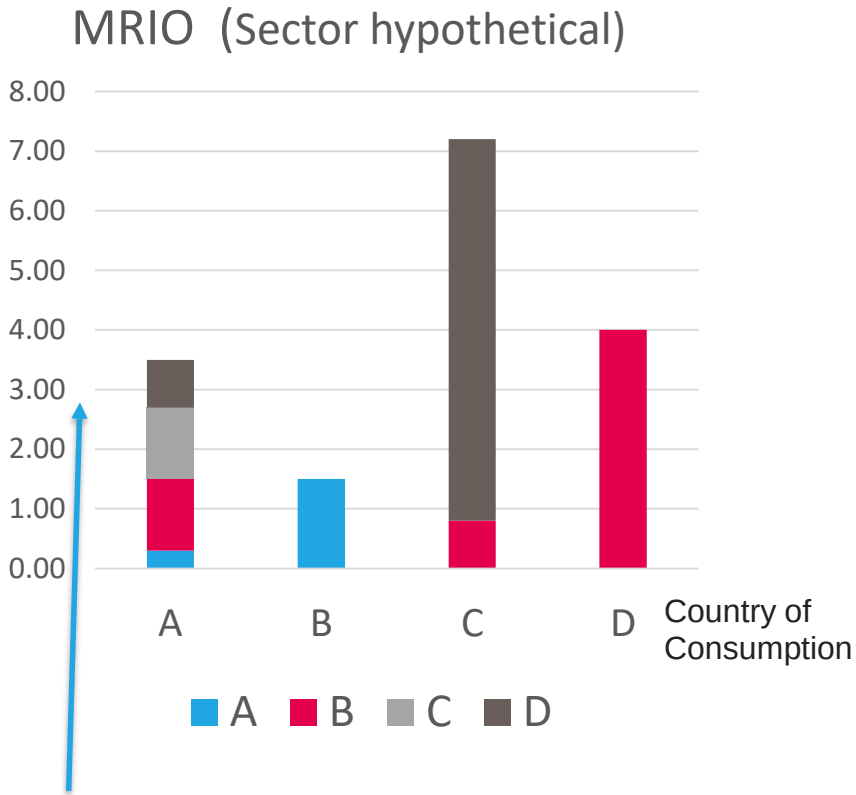
Comparing land use impact by sourcing countries:
Misrepresenting location and or technology might largely increase uncertainties



Country D has lowest land use intensity per kg of soybean



Country B has the highest land use intensity per kg of soybean



Scale difference: It's no longer representing soybean anymore due to severe sector aggregation.

Conclusion, Insights and Outlook

- Physical/economic flows and network models enable tracking supply chain locations

✓ Distant/network impact can be modelled. All models (Leontief, Ghosh or activity/market) yield equivalent results

✓ Physical trade flow (PTF) such as FAOSTAT has limited sector coverage, high product specification

✓ Monetary MRIO has more sectors, low product specifications and geographical relevance due to aggregation

✓ PTF and Monetary MRIO each have merits and pitfalls: crucial to weigh uncertainty and acceptable data quality

✓ Models can incorporate various data and model impacts across different spatial and temporal scale

- Practical considerations and further development

✓ Improve spatio-temporal scale and resolution

- ❖ Spatial resolution: from national to subnational/ regional based on statistics or optimization approaches
- ❖ Temporal resolution: from yearly to seasonally or monthly

✓ Examine constraints, be realistic, refine and validate (import/export) assumptions & results with empirical data

✓ Integrate with macro economic or simulation models to estimate indirect/leakage impact and predict future scenarios

✓ Future infrastructure: semantic linked data, knowledge models and ontology platform (describe, harmonize and link)

Stay strategical, stay pragmatic.

THANK YOU!

IF YOU WOULD LIKE TO LEARN MORE PLEASE CONTACT

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