Extractions, Decompositions, Value Chains, and Frameshifting

Michael L Lahr

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Outline

- 25 years ago…
- Under the hood…
  - Aggregation
  - Disclosure issues and missing data
  - The explicit identification of trade in macro models
  - Employing "superior" data
- Parting wisdom

My backward linkages (credentials?)

- Regional Science
- Taught as a undergraduate by **Ronald E. Miller** & **Peter D. Blair** (2)
- Course with **Walter Isard**
- My PhD committee:
  - **Ronald E. Miller**
    - Student of Robert Kuenne
      - Student of Wassily Leontief
  - **Bejamin H. Stevens**—applied economist/planner
    - Student of Isard
  - **Janusz Szyrmer**—intuitive theorist
    - Student of Miller &
    - Student of Blair
      - Student of Miller
    - Student of Isard
      - Colleague of Leontief
  - **Richard S. Conway**—applied econometrician

    (see Szyrmer)
    - Student of Lawrence Klein

I-O and me

"You are what you is." –Frank Zappa

- Started out thinking I would emphasize planning theory, perhaps using Pontryagin's principle. A world of
  - Hamiltonians
  - Jacobians
  - Bordered Hessians
- Transferred to ideas in location theory
  - The lesson from Asami-san
- Return to the promised land
  - Hot stuff in mathematics of I-O was important sectors and cells
  - The work of Rod Jensen & Guy West
- Marital influences and a visit to Rhode Island

What this talk is NOT

- Something I cobbled together quickly
- Some old American guy telling you
  - What he his future work will center upon
  - What you should be working on
  - What he believes is the future of I-O
- An overview of the new material in Miller & Blair (2009)

What it IS

- A reconnaissance through the world of I-O
  - Shows my biases (so you know better how to consume my talk)
  - Shows what our field has risen from
- A view of
  - I-O concepts that are probably not worth pursuing
  - What is important/hot in I-O now
  - The work that I think **should** be done

1. I-O world as it was 25 years ago

A. Finally overcome basic calculation issues
   - Computer architecture only limits very large matrices

B. The death knell?
   - UN and national government funding dried up
   - Belief in the rigor and stochastic nature of regression econometrics rises at the expense of other linear models

1. I-O world 25 years ago (cont'd)

C. A Leontief-Isard divide

- Leontief followers: **How does technology change affect labor?**
  - ✓ Firm size distribution
  - ✓ Labor types/income distribution
  - ✓ Pollution levels
  - ✓ How rapidly does I-O technology change in a significant manner?
- Isard followers: **Build a better mouse trap more efficiently**
  - ✓ Spatial disaggregation
  - ✓ Maximum viable use of the minimal available data
    - ✓ Interregional trade estimation
    - ✓ How much does technology usage differ across space?

D. Common Ground

The Regional I-O Gospel

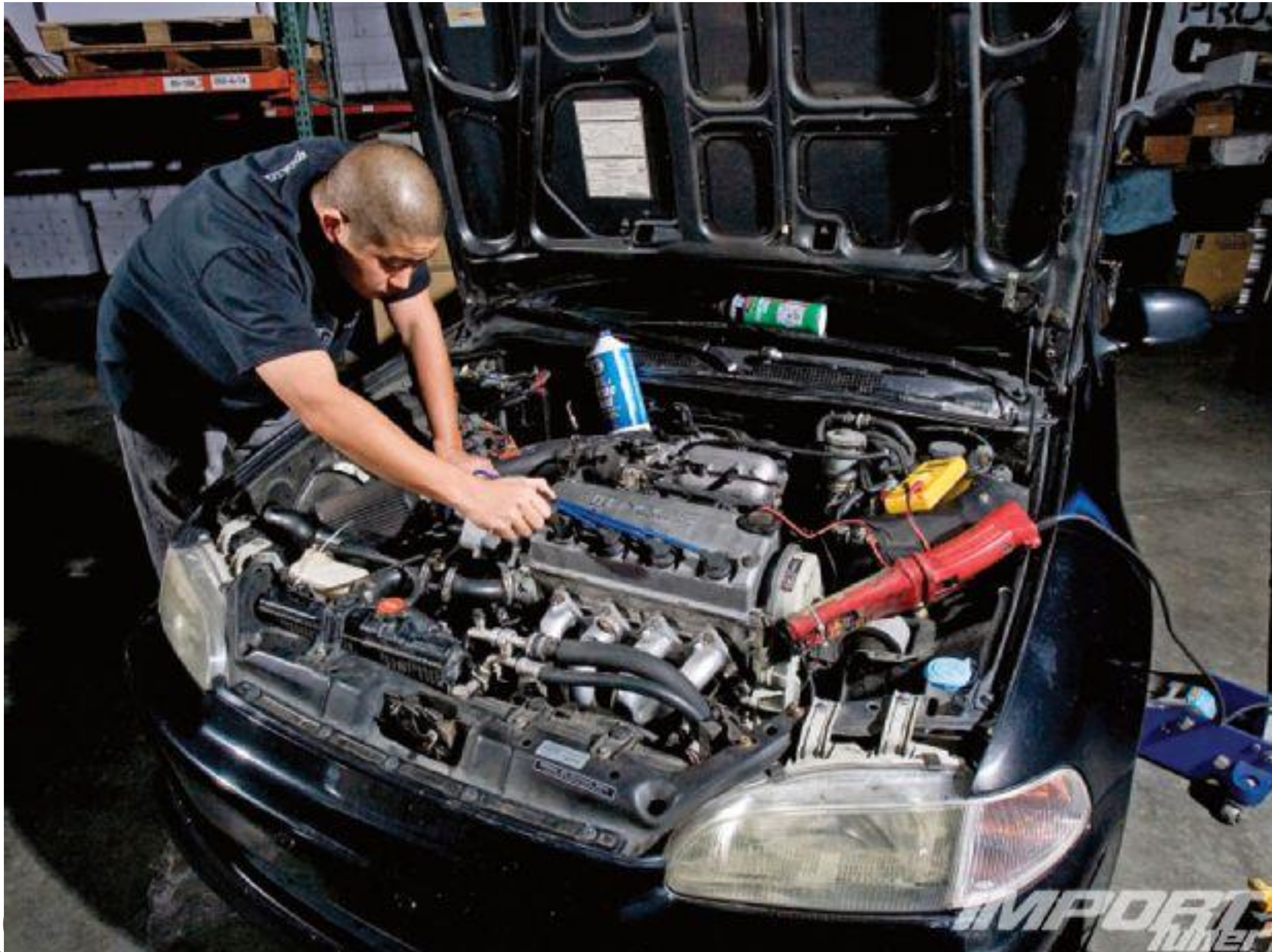
according to Hewings & Jensen (1988, 22[1], 43-53)

- “Rapid growth in adoption of input-output analysis for planning, forecasting and general impact analyses in countries of all persuasions”
- Decline in attention in the production of regional input-output tables & movement toward development of hybrid input-output tables
  - Returned attention to the sensitivity of I-O structures to error/bias
  - New attention to the notion of key sectors
- Rise in the integration of I-O models with other mathematical economic models, plus more sophisticated balancing techniques

A blueprint for regional analysts for years to come

Common Ground:
Why IIOA's founding was important

- Sharing of research broadened perspectives of all
  - Regional I-Onicks had lost sight of some ultimate uses of I-O
  - National statistical offices had some things to learn from the focuses technical work of regional analysts
- Provided a publication outlet for what mainstream economists viewed as a dead-end field
  - Shows field still alive and well
  - Enables field to expand
    - SAMs/CGE
    - Systems econometric modeling
    - Global value change
- Coincides with internet and e-mail usage
- For me: The work of Erik Dietzenbacher & Eric Howe



2. Aggregation—aka Sectoral Detail

- If different sectors can have different multipliers, then level of aggregation matters, except when there is…
- Perfect aggregation
  - must be substitutes or complements
  - must have same production function
- **In the I-O world, we tend to need more industry detail not less**

Spurious Aggregation Error:

The case of the unwary user

Case 1: Impact of the demand for primary metals (aluminum in a steel-producing region)

Case 2: Impact of demand for fabricated metals (in a steel-producing region)

- Corollary 1: Aggregation error is smaller in economies diversified in parallel to nation
- Corollary 2: Aggregation error is smaller when effects are less than direct

3. Microeconomics of Trade & Macro Models: The Gravity Model

$$F_{ij} = G\frac{M_i M_j}{D_{ij}}$$

Elegance despite a lack of full economic foundation. Used to measure:

- Trade (Home bias)
- Access to services
- Trip distribution by transport mode
- Migration propensities
- Location of facilities

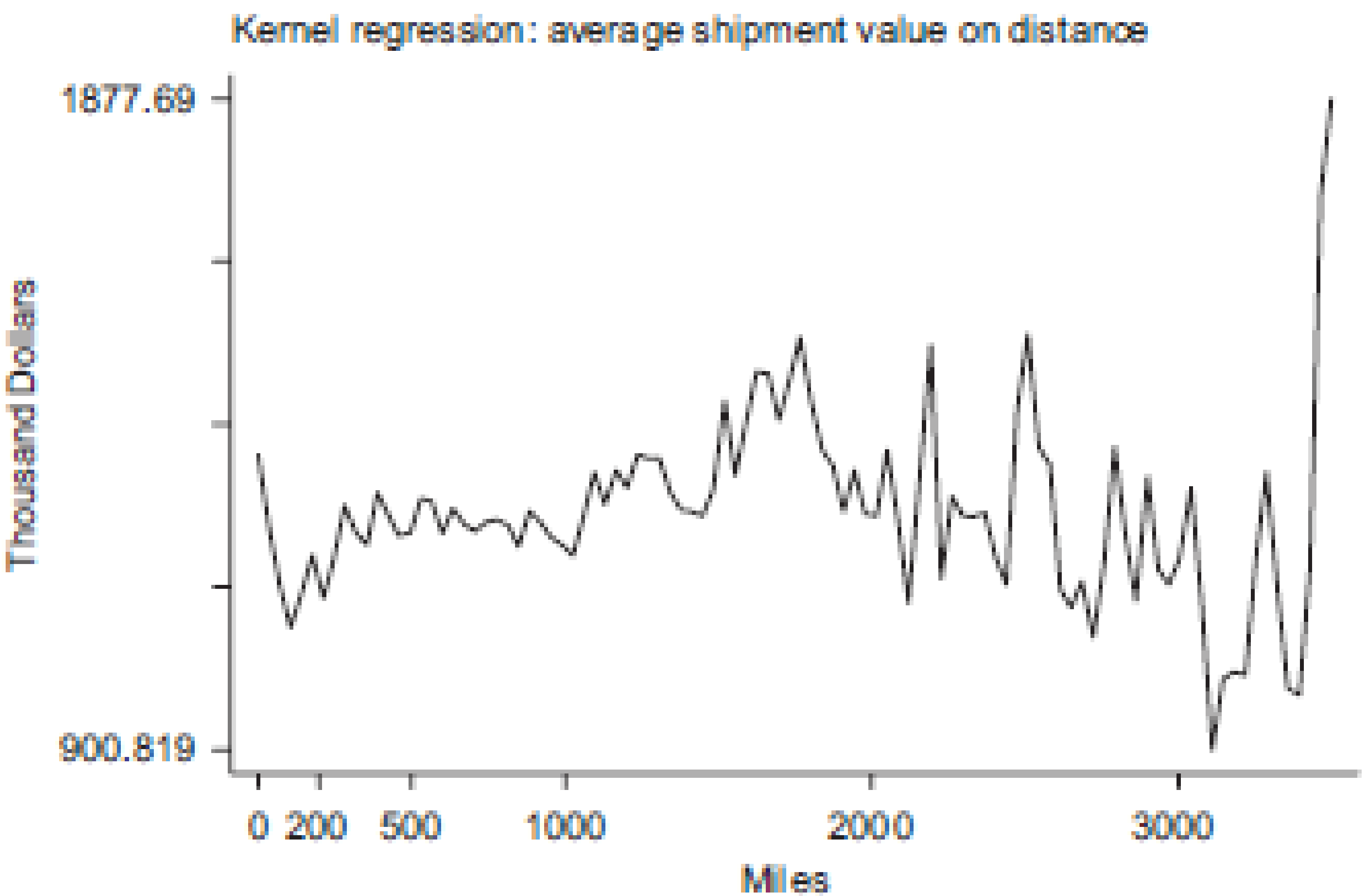
The Gravity Model cont'd

Proxies for ***<u>all</u>*** costs of doing business from/at a distance

- Imperfect information & lack of tacit signals
- Different
  - legal systems
  - Standards
  - cultures
  - Languages

- Gravity model captures all of the above, leading to a hypothesis of a so-called "home bias" to trade
  - Strangely, a couple of studies have found a <u>negative</u> home bias beyond at some borders…more trade beyond the border than within it!!??

Microeconomics of Trade



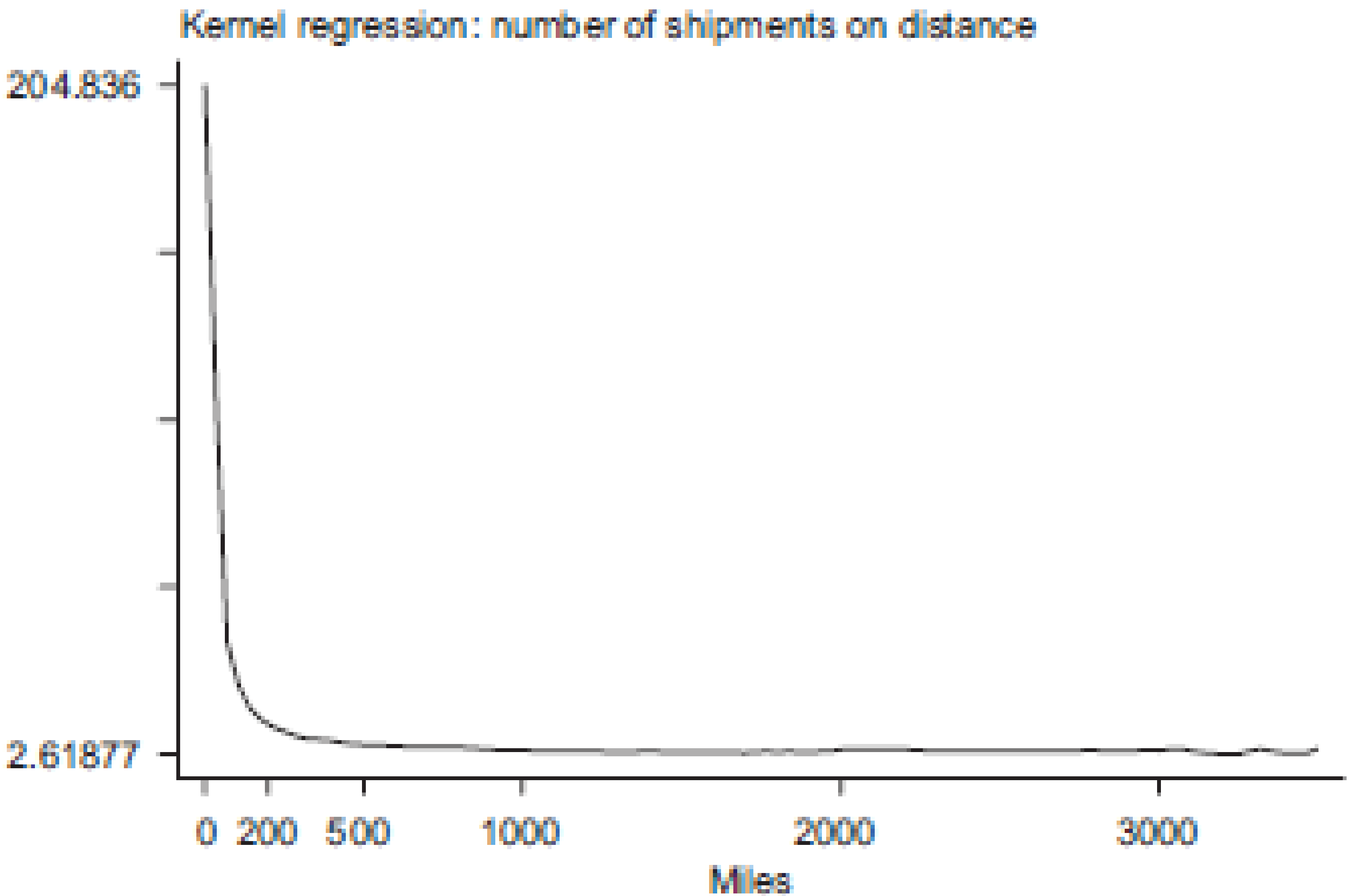


Fig. 2. Kernel regressions.

R. Hillberry, D. Hummels / European Economic Review 52 (2008) 527–550

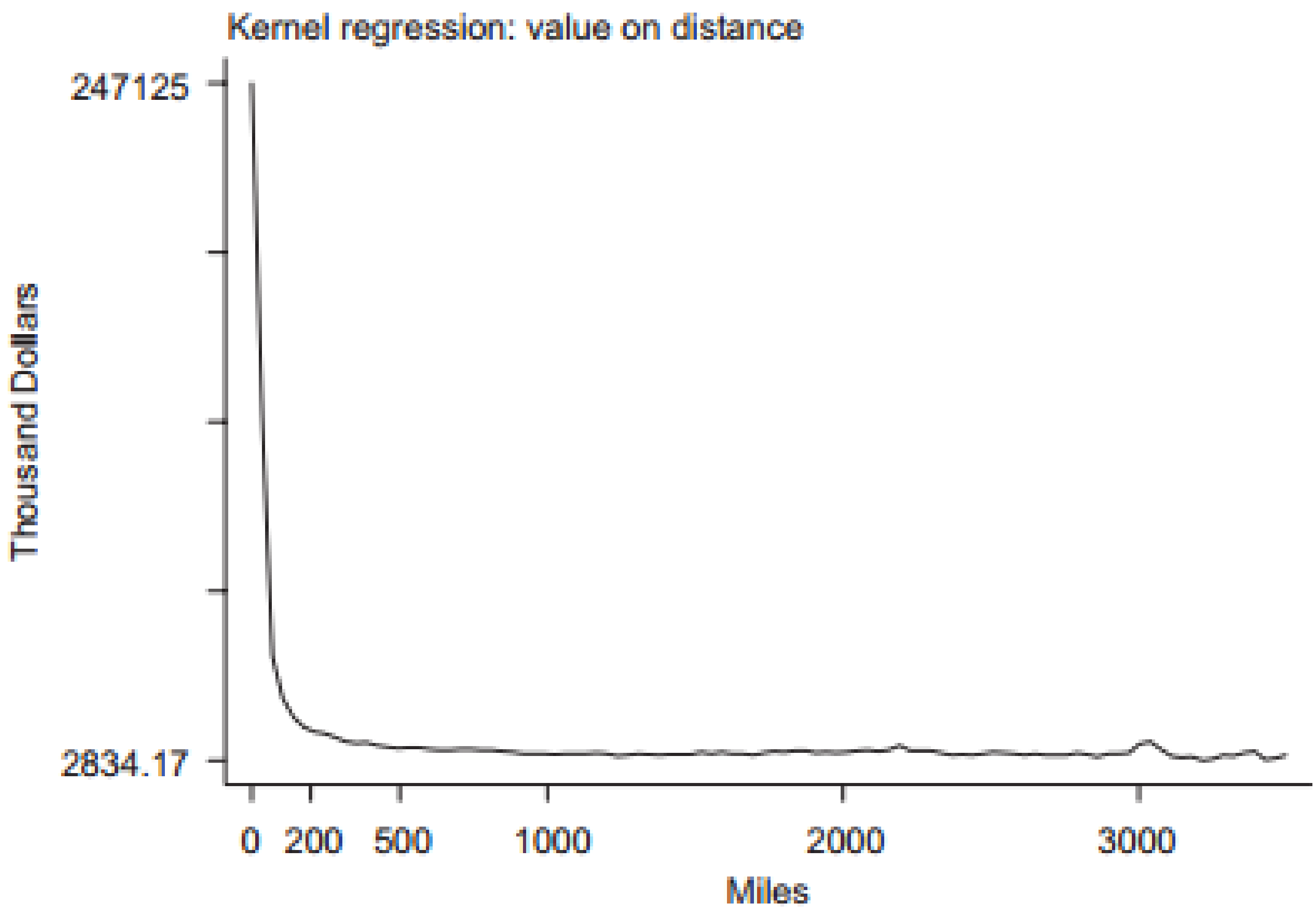
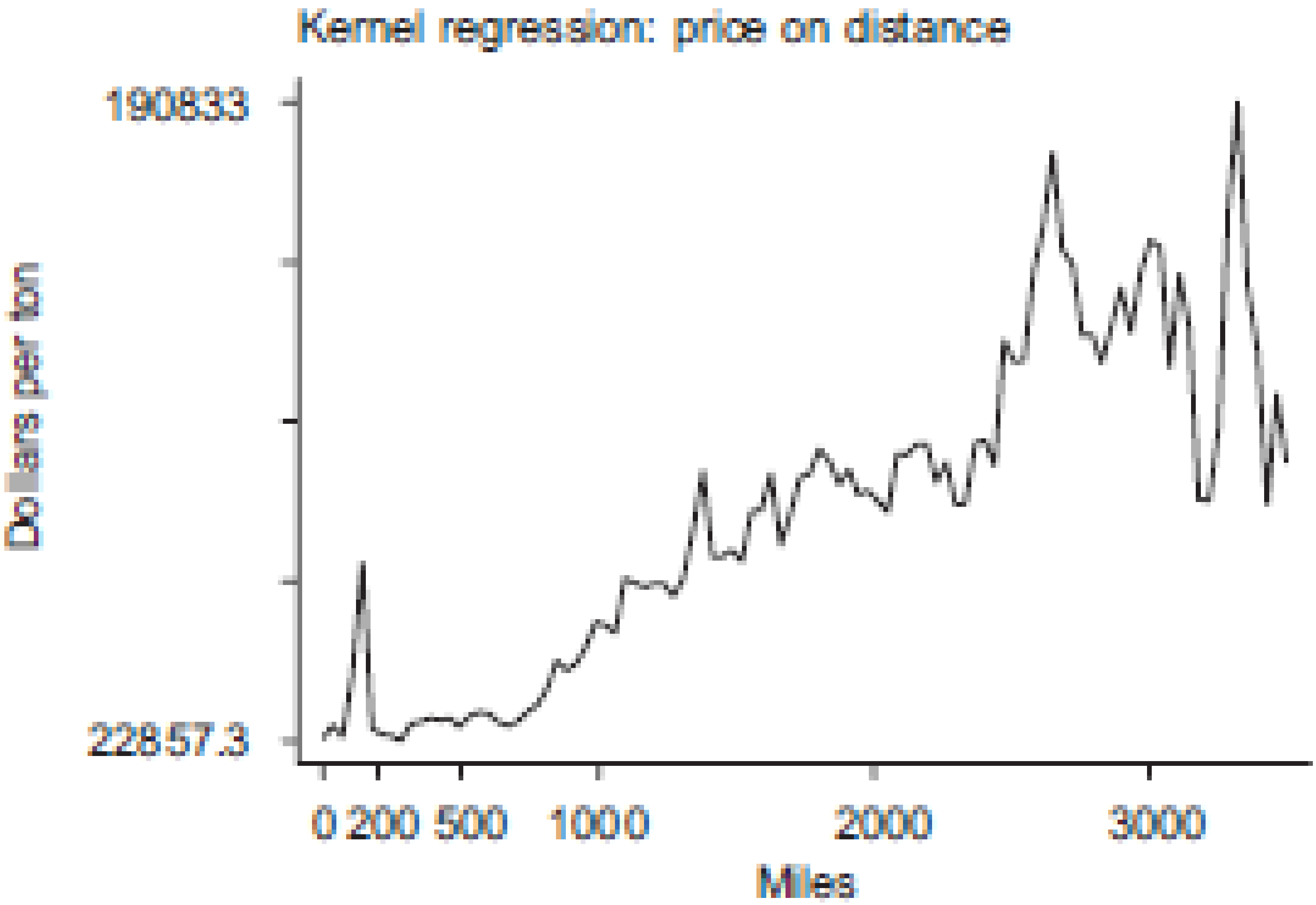


Fig. 1. Kernel regressions.



Kernel regression: price on distance
190833
228 57.3
Dollars per ton
0 200 500 1000 2000 3000
Miles

According to Hilberry and Hummels…

- With distance…
  - # commodities shipped declines “dramatically”
  - # of establishment-destination pairings declines “dramatically”
- With I-O intermediate demand
  - “up- and down-stream establishments sort themselves geographically to avoid spatial frictions”
  - Largely within 8 km!!!

Implications to I-O trade modeling

- Implication that intra- and inter-national (regional) trade should be estimated differently.
  - By commodity? How detailed?
  - Also by transport mode?
  - Econometrically weight using industry "distances"???

Relationships in regional I-O lit

- A handful of variables are used to estimate Regional Purchase Coefficients (RPCs) econometrically since 1983:
  - The local area's intermediate demand for the commodity,
  - The commodity's weight-to-value ratio,
  - The area's share of the national land area (distance),
  - The area's relative firm size for suppliers of the commodity (productivity?),
  - The area's share of national supply of the commodity, (productivity?)
  - A set of binary variables designed to express remaining interindustry and interregional cost differentials.

4. Revealing disclosure problems?

- Describing the typical problem:
  - Three measures—establishments, employment, and payroll—in at least two hierarchical forms: spatial and industry units
  - Data on industries with 5(?) or less establishments not released
    - Done to assure information nondisclosure for reasons of industry competition
    - Another "similar" industry with no disclosure too
  - National level: all data for most detailed industries
  - At spatial levels (state & county)
    - Totals for each region available for each measure
    - Some data reported for various industry levels (2-, 3-, 4-, 5-, 6-digit)
- How to fill in the disclosure issues at least for level of benchmark national I-O industries?

Data raking with priors!!!

What to use as priors?

- *Nearest spatial level in industry*

  OR

- *Nearest industry in same space?*

- Which proxy?
  - Employees per establishment
  - Payroll per employee
  - Similar data from a less reliable source

What method to use?

- RAS?
- Minimize sum of information distance from *all* priors?
  - But we may have a better idea of some than others
    - How might we incorporate data on information reliability?

5. Incorporating survey data into SAMs

- Assume we have a set of regional or national I-O accounts
  - Some nations have data on aggregates by region for
    - Household consumption (details?)
    - Expenditures and revenues of
      - Local governments
      - State governments
      - National government within a region
    - Interregional trade
    - Components of GDP
  - Further some of us can get specific data for
    - A sub-industry
    - A representative sample of establishments in an industry
    - Updates on technology for aggregate industries

Some Words of Wisdom

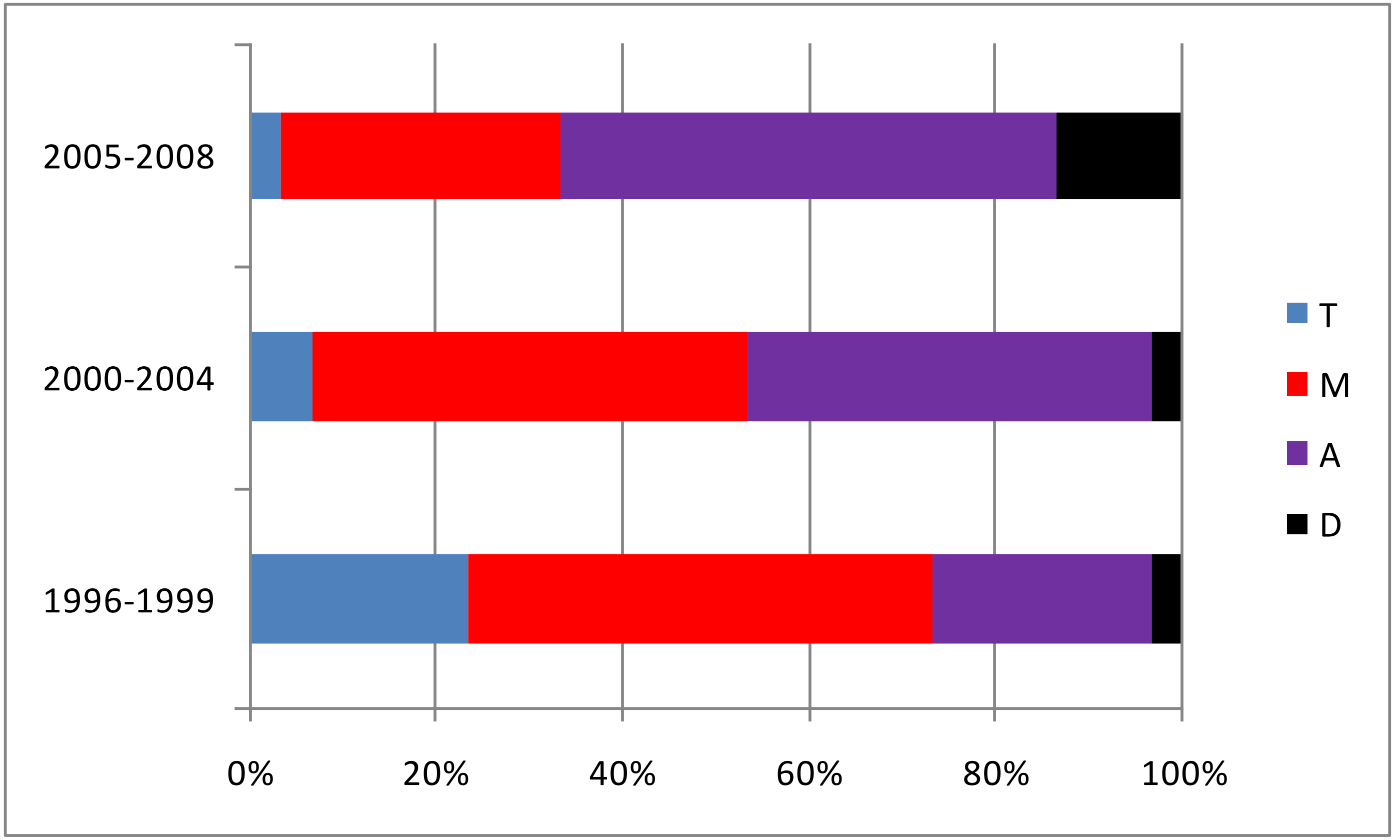
Lesson 1: Basic research principles

1. Work only on material you like to work on.
2. Work only with ***people you like to work with***.
3. Learn the political and accounting systems of your research institution and exploit them to your best advantage
4. Try to publish all of what you write …somewhere

Lesson 2: Method or Application?

- The average person understands topical matter, not methods
  - My Rutgers colleagues don't know what I do: I seem to them a square peg in a round hole
  - Until lately Erik's non I-O colleagues at Groningen believed he only played with the mathematics of matrices
- Mathematics is a universal language: it enables an international understanding
  - Your closest colleagues and main pool of potential students can be on the other side of the globe
- Ideally, new methods are applied.

Shift in Nature of I-O Articles



Source: Los, Bart. (2011) "The Output of Input-Output Analysis: A Bibliometric Study (1996-2008)," 19th International Input-Output Conference, June 14.

Most Important Outlets (entire period)

Ecological Economics		83
Energy Policy		45
Journal of Industrial Ecology		40
Annals of Regional Science		31
Environment and Planning A		25
Regional Studies		24
International Journal of Life Cycle Assessment		23
Journal of Regional Science		22
Environmental Science and Technology		21
International Journal of Production Economics		19

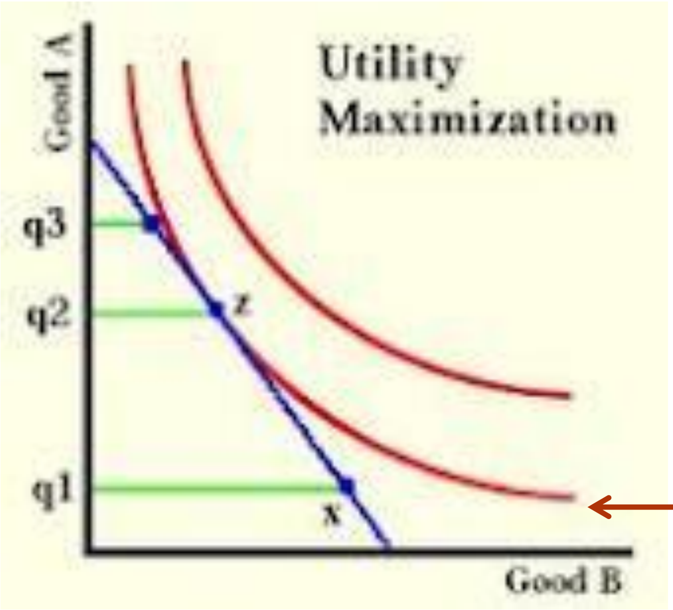
Source: Los, Bart. (2011) "The Output of Input-Output Analysis: A Bibliometric Study (1996-2008)," 19th International Input-Output Conference, June 14.

Economic Systems Research: 154

Lesson 3: Publish what's hot

- Follow the cash
- Follow the impact factor

Publish your passion!



Recall Lesson 1: Doing what you like to do?

Lesson 4: What IS hot?

- Modeling Climate Change
- Environmental Analysis
- Energy Analysis
- Structural Decomposition Analysis
- Inter-areal comparisons
- Work on China, India, Latin America, Africa, and other developing nations
- Analyses of Recessions
- Examinations of the Repercussions of Financial Collapse
- Simulations of Disasters
- Trade Estimation
- Adding Dynamics and Stochastics to Modeling
- Value chains

Lesson 5: What IS not (hot).

- Supply-side modeling in an I-O framework
- The bias of multipliers in a stochastic setting
- SDA using roughly estimated regional tables
- Economic impacts using I-O/CGE models
- Key sector work in a static setting

Lesson 6: Work that needs to be done

- Decomposition of growth using a dynamic model (Masahiro Kuroda & Koji Nomura, 2004)
- Multisectoral growth theory & DSGEs?
- Association of eigenvalues and aggregation bias/error?
- The value of Average Propagation Lengths (APLs)?
- Dynamic extensions of key sectors
- Interpretations of the Leontief inverse in time?
- Can one properly measure forward linkages?
- How to properly compare input-output tables

Multipliers & Linkages

Section Outline

1. Recalling the Leontief inverse
2. Round-by-round approach revisited
3. Output multipliers
4. Income, employment, and value added multipliers
5. Model closure
6. Intermediate Output Multpliers

Recalling the Leontief Inverse

- Let $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = (\mathbf{I} - \mathbf{D}\hat{\boldsymbol{\rho}}\mathbf{B})^{-1}$, in an industry-by-industry setting

$$\Delta\mathbf{f} = (\Delta\mathbf{F} \cdot \mathbf{i})$$

also let $\Delta\mathbf{g} = \mathbf{L} \cdot \Delta\mathbf{f}$

then $$\Delta\mathbf{g} = (\mathbf{I} - \mathbf{A})^{-1}(\Delta\mathbf{F} \cdot \mathbf{i})$$

- Now what did I say about **L?**
- What is $\Delta\mathbf{g}$ if $\Delta\mathbf{f}$ is a forecast of investments in improving highways?
- What necessarily must the content of $\Delta\mathbf{f}$ be?

The Round-by-Round Approach

- Recall that we also know

  $\mathbf{Lf}=\mathbf{f}+\mathbf{Af}+\mathbf{A}(\mathbf{Af})+\mathbf{A}(\mathbf{A}(\mathbf{Af}))+\mathbf{A}(\mathbf{A}(\mathbf{A}(\mathbf{Af})))+\mathbf{A}(\mathbf{A}(\mathbf{A}(\mathbf{A}(\mathbf{Af}))))$

  …

  After 7-8 rounds the difference between **Lf** and the RHS tends to be very small, less than 1%.
- Three rounds tailored to the problems can be quite sufficient.
- A survey of some sort must be applied.
- How should surveying be done?

Output Multipliers

- So **L** is the Leontief inverse
- It is also known as the "total requirements matrix"

  Reveals the total requirements from the economy of some final demand
- What do the elements of **L** tell you?
- Then, what does a column sum of **L** tell you?
- What is **i'L**?

Character of A on L

- Greater value added reduces output multiplier size
- Largest coefficients and larger interindustry transactions are the most influential
  - How large is "large"?
  - $\mathbf{i}'\mathbf{g}/n^2$?
- Implications for resurveying?
- Hybrid tables?

Other Multipliers

- How can we derive
  - an income multiplier?
  - a job multiplier?
  - a GDP or value-added multiplier?
  - energy use? (be careful!)
  - environmental effects?

Model Closure

- Leontief's original model took a Keynesian perspective
- What if we instead also closed the model with respect to
  - households?
  - local government?
  - state government?
  - federal government?
- When might we wish to close a model for each of the above?
- Can we extend the above to a model of the earth and also close the model to exports?

Intermediate Output Multipliers

- But what if we want to find out
  - How the casino sector has affected the economy?
  - How active transportation has contributed to our economic well-being?
  - What would happen if a manufacturer should leave our country?
  - The contribution of port activity to an economy?
  - What Rutgers University means to the state's economy?

$$\Delta \mathbf{g} = \mathbf{L}\hat{\mathbf{L}}^{-1}\Delta\tilde{\mathbf{g}}, \text{ where } \Delta\tilde{\mathbf{g}} \text{ is some change in intermediate output}$$

  - What is the $\hat{\mathbf{L}}^{-1}$ doing?

Notion of Key Sectors

- Alfred Hirschman (1958)

  The Strategy of Economic Development

  - Chenery and Watanabe *(1958)*
  - Rasmussen (1957)
- By 1976 scholar use Leontief and Ghosh output multipliers

Supply-side model

- Ambica Ghosh (1958)
  - Rather than $\mathbf{g}=\mathbf{Xi}+\mathbf{f}$ he suggests $\mathbf{g}'=\mathbf{iX}+\mathbf{v}'$, which implies

$$\mathbf{g}' = \mathbf{v}'(\mathbf{I}-\mathbf{C})^{-1}$$

where $\mathbf{X} = \hat{\mathbf{g}}\mathbf{C}$ and **C** is the direct allocation matrix.

$$\mathbf{G}=(\mathbf{I}-\mathbf{C})^{-1}$$

  - As with Leontief's model, in which we assume technology relationships are fairly fixed, Ghosh's assumes production allocations are stable
  - In what kinds of economies can we expect supply distributions are stable?
  - Scholars have shown a stable **A** necessarily implies an unstable **C**
  - Reinterpreted as a price model. Implications?

Hypothetical Extraction 1

What would happen if some aspect of a sector, say sector *j*, is removed from the economy?

(Paelinck, de Caevel, and Degueldre, 1965; Strassert, 1968)

- One can simply set all values of the sector to zero, recalculate A (say to $\bar{\mathbf{A}}$), and estimate the differential effect of $\Delta\mathbf{f}$ on $\mathbf{g}$.

$$\mathbf{i}'\mathbf{g} - \mathbf{i}'\overline{\mathbf{g}}$$

Partitioned Structure

$$\mathbf{A} = \left[\begin{array}{c|c} \mathbf{A}_{11} & \mathbf{A}_{12} \\ \hline \mathbf{A}_{21} & \mathbf{A}_{22} \end{array}\right] \qquad \mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \left[\begin{array}{c|c} \mathbf{H} & \mathbf{H}\mathbf{A}_{12}\boldsymbol{\alpha}_{22} \\ \hline \boldsymbol{\alpha}_{22}\mathbf{A}_{21}\mathbf{H} & \boldsymbol{\alpha}_{22}\left(\mathbf{I} + \mathbf{A}_{21}\mathbf{H}\mathbf{A}_{12}\boldsymbol{\alpha}_{22}\right) \end{array}\right]$$

where $\mathbf{H} = (\mathbf{I} - \mathbf{A}_{11} - \mathrm{A}_{12}\alpha_{22}\mathrm{A}_{21})^{-1}$ and $\boldsymbol{\alpha}_{22} = (\mathbf{I} - \mathbf{A}_{22})^{-1}$

Final demands and gross outputs can be partitioned similarly

$$\mathbf{f} = \left[\begin{array}{c} \mathbf{f}_1 \\ \hline \mathbf{f}_2 \end{array}\right] \qquad \mathbf{g} = \left[\begin{array}{c} \mathbf{g}_1 \\ \hline \mathbf{g}_2 \end{array}\right]$$

So

$$\mathbf{g} = \left[\begin{array}{c} \mathbf{g}_1 \\ \hline \mathbf{g}_2 \end{array}\right] = \left[\begin{array}{c|c} \mathbf{H} & \mathbf{H}\mathbf{A}_{12}\boldsymbol{\alpha}_{22} \\ \hline \boldsymbol{\alpha}_{22}\mathbf{A}_{21}\mathbf{H} & \boldsymbol{\alpha}_{22}\left(\mathbf{I} + \mathbf{A}_{21}\mathbf{H}\mathbf{A}_{12}\boldsymbol{\alpha}_{22}\right) \end{array}\right] \left[\begin{array}{c} \mathbf{f}_1 \\ \hline \mathbf{f}_2 \end{array}\right]$$

Hypothetical Extraction 2

- From a purely mathematical viewpoint, three kinds of "extraction."
- One can remove from (replace with null matrices) the partitioned **A** matrix:
  1. All three submatrices in which sector 1 plays a role;
  2. Any pair of the three submatrices; and
  3. Any one of them

Hypothetical Extraction 3.1

Case 1. Extract all three matrices in which sector 1 has an influence.
Set $\mathbf{A}_{11} = \mathbf{A}_{12} = \mathbf{A}_{21} = \mathbf{0}$, so

$$\mathbf{A}^1 = \left[\begin{array}{c|c} \mathbf{0} & \mathbf{0} \\ \hline \mathbf{0} & \mathbf{A}_{22} \end{array}\right]$$

Then, the Leontief inverse is

$$\mathbf{L}^1 = \left[\begin{array}{c|c} \mathbf{I} & \mathbf{0} \\ \hline \mathbf{0} & \boldsymbol{\alpha}_{22} \end{array}\right]$$

This is the approach of Meller and Marfan (1981), and the sector is fully removed

$$\Delta\mathbf{g} = \mathbf{Lf}\text{-}\mathbf{L}^1\mathbf{f}^1$$

Hypothetical Extraction 3.2a

Case 2a. $\mathbf{A}_{12} = \mathbf{A}_{21} = \mathbf{0}$.

$$\mathbf{A}^{2a} = \left[\begin{array}{c|c} \mathbf{A}_{11} & \mathbf{0} \\ \hline \mathbf{0} & \mathbf{A}_{22} \end{array}\right]$$

$$\Delta\mathbf{g} = \mathbf{Lf} - \mathbf{L}^{2a}\mathbf{f}^{2a} \quad \mathbf{L}^{2a} = \left[\begin{array}{c|c} \boldsymbol{\alpha}_{11} & \mathbf{0} \\ \hline \mathbf{0} & \boldsymbol{\alpha}_{22} \end{array}\right]$$

Here the sector's linkages to other sectors are eliminated

Hypothetical Extraction 3.2a

Case 2b. $\mathbf{A}_{11} = \mathbf{A}_{21} = \mathbf{0}$.

$$\mathbf{A}^{2\mathrm{b}} = \left[\begin{array}{c:c} \mathbf{0} & \mathbf{A}_{12} \\ \hdashline \mathbf{0} & \mathbf{A}_{22} \end{array}\right]$$

$$\mathbf{L}^{2\mathrm{b}} = \left[\begin{array}{c:c} \mathbf{I} & \mathbf{A}_{12}\boldsymbol{\alpha}_{22} \\ \hdashline \mathbf{0} & \boldsymbol{\alpha}_{22} \end{array}\right]$$

Here, the sector still produces but imports all of its inputs

Other Extractions

$$\mathbf{A}^{2c} = \left[\begin{array}{c:c} \mathbf{0} & \mathbf{0} \\ \hdashline \mathbf{A_{21}} & \mathbf{A_{22}} \end{array}\right]$$

$$\mathbf{A}^{3a} = \left[\begin{array}{c:c} \mathbf{A_{11}} & \mathbf{0} \\ \hdashline \mathbf{A_{21}} & \mathbf{A_{22}} \end{array}\right] \qquad \mathbf{A}^{3b} = \left[\begin{array}{c:c} \mathbf{A_{11}} & \mathbf{A_{12}} \\ \hdashline \mathbf{0} & \mathbf{A_{22}} \end{array}\right] \qquad \mathbf{A}^{3c} = \left[\begin{array}{c:c} \mathbf{0} & \mathbf{A_{12}} \\ \hdashline \mathbf{A_{21}} & \mathbf{A_{22}} \end{array}\right]$$

And of course, the Ghosh equivalents…

Even more?

- What if a subsector or firm leaves?

$$\bar{\mathbf{A}} = \mathbf{A} - \alpha \mathbf{e}_k \mathbf{b}'_k, \tag{2}$$

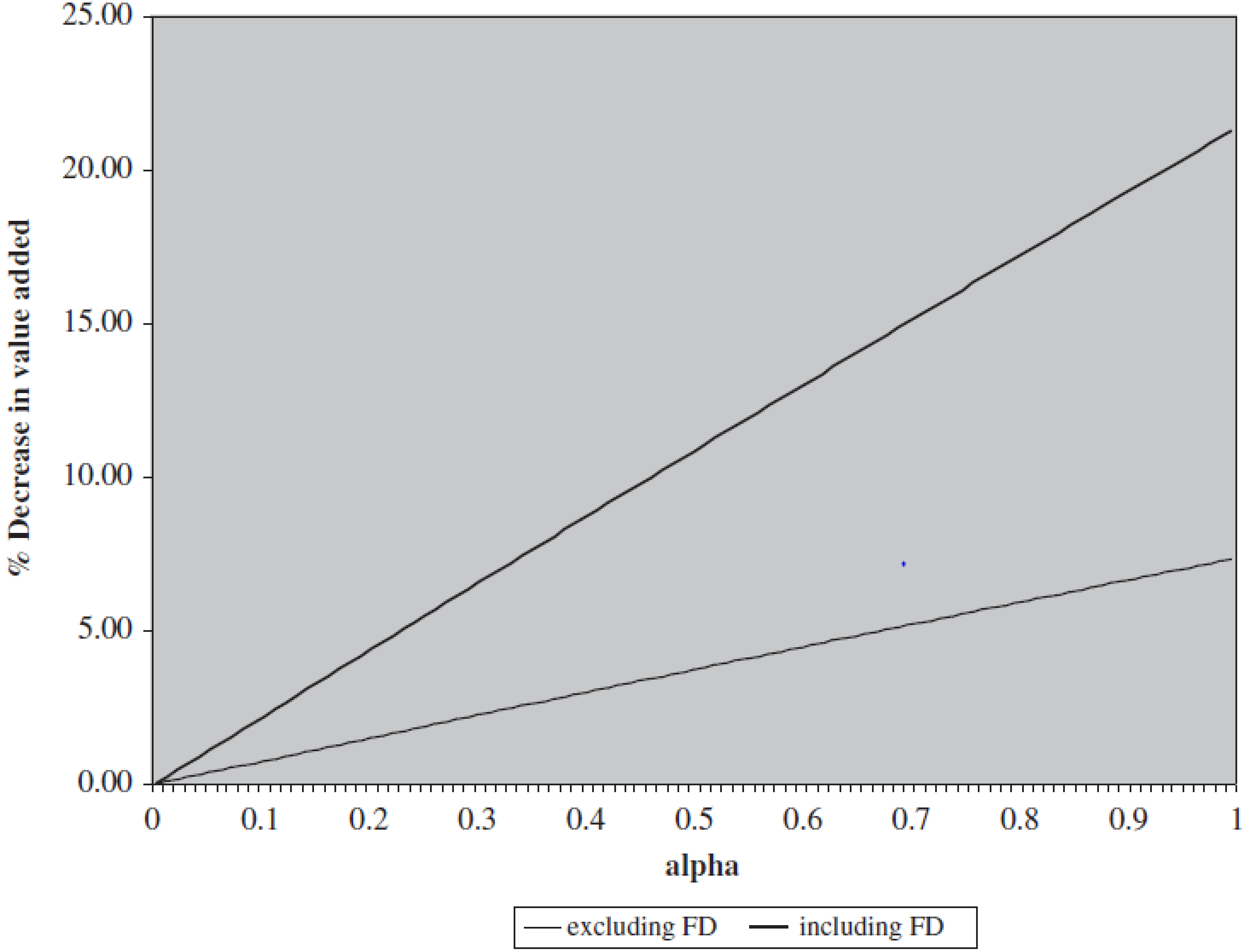
where $\mathbf{e}_k$ indicates the kth unit vector with a one in element k and zeros elsewhere and $\mathbf{b}'_k = (a_{k1}, a_{k2}, \ldots, a_{k,k-1}, 0, a_{k,k+1}, \ldots, a_{kn})$. We, therefore, have $\mathbf{I} - \bar{\mathbf{A}} = \mathbf{I} - \mathbf{A} + \alpha \mathbf{e}_k \mathbf{b}'_k$. Because $\bar{\mathbf{A}}$ is the sum of the prior direct matrix $\mathbf{A}$ and another matrix, one can readily express its Leontief inverse using techniques – for the inverse of the sum of two matrices – summarized in an excellent review by Henderson and Searle (1981). This yields

$$\bar{\mathbf{L}} = \mathbf{L} - \frac{\alpha \mathbf{L} \mathbf{e}_k \mathbf{b}'_k \mathbf{L}}{1 + \alpha \mathbf{b}'_k \mathbf{L} \mathbf{e}_k}. \tag{3}$$

For element (i, j) of the difference between the two Leontief inverses, we then have

$$\bar{l}_{ij} - l_{ij} = -\frac{\alpha \mathbf{e}'_i \mathbf{L} \mathbf{e}_k \mathbf{b}'_k \mathbf{L} \mathbf{e}_j}{1 + \alpha \mathbf{b}'_k \mathbf{L} \mathbf{e}_k} = -\frac{\alpha l_{ik} \mathbf{b}'_k \mathbf{L} \mathbf{e}_j}{1 + \alpha \mathbf{b}'_k \mathbf{L} \mathbf{e}_k}. \tag{4}$$

FIGURE 1. The relationship between the extent of partial extraction (alpha) and the percentage decrease in total value added.



Structural Decomposition Analysis

Aim of SDA

To disentangle the change in some variable
and decompose it into changes in its underlying components

Similarities with:

- Growth accounting
- Shift-share analysis
- Index decomposition analysis: Paasche & Laspeyers

But typically applied in an input-output framework

Starting out

Output $\mathbf{x} = \mathbf{Lf}$

Consider the change in output: $\mathbf{x}_1 - \mathbf{x}_0$

$$\begin{aligned} \mathbf{x}_1 - \mathbf{x}_0 &= \mathbf{L}_1\mathbf{f}_1 - \mathbf{L}_0\mathbf{f}_0 \\ &= \mathbf{L}_1\mathbf{f}_1 (- \mathbf{L}_1\mathbf{f}_0 + \mathbf{L}_1\mathbf{f}_0) - \mathbf{L}_0\mathbf{f}_0 \\ &= (\mathbf{L}_1\mathbf{f}_1 - \mathbf{L}_1\mathbf{f}_0) + (\mathbf{L}_1\mathbf{f}_0 - \mathbf{L}_0\mathbf{f}_0) \\ &= \mathbf{L}_1(\Delta \mathbf{f}) + (\Delta\mathbf{L})\mathbf{f}_0 \end{aligned}$$

Interpretation:

what would have been the change in the outputs
if only **L** had changed as it actually did
but anything else (here **f**) would have remained the same (*ceteris paribus*)

Now treat it like an index

Output $\mathbf{x} = \mathbf{Lf}$

Consider the change in output: $\mathbf{x}_1 - \mathbf{x}_0$

$$
\begin{aligned}
\mathbf{x}_1 - \mathbf{x}_0 &= \mathbf{L}_1\mathbf{f}_1 - \mathbf{L}_0\mathbf{f}_0 \\
&= \mathbf{L}_1\mathbf{f}_1 \ (- \mathbf{L}_1\mathbf{f}_0 + \mathbf{L}_1\mathbf{f}_0 \ ) - \mathbf{L}_0\mathbf{f}_0 \\
&= (\ \mathbf{L}_1\mathbf{f}_1 - \mathbf{L}_1\mathbf{f}_0 \ ) + (\ \mathbf{L}_1\mathbf{f}_0 - \mathbf{L}_0\mathbf{f}_0 \ ) \\
&= \mathbf{L}_1(\Delta \mathbf{f}) + (\Delta \mathbf{L})\mathbf{f}_0
\end{aligned}
$$

Alternatively:

$$
\begin{aligned}
\mathbf{x}_1 - \mathbf{x}_0 &= \mathbf{L}_1\mathbf{f}_1 - \mathbf{L}_0\mathbf{f}_0 \\
&= \mathbf{L}_1\mathbf{f}_1 \ (- \mathbf{L}_0\mathbf{f}_1 + \mathbf{L}_0\mathbf{f}_1 \ ) - \mathbf{L}_0\mathbf{f}_0 \\
&= (\ \mathbf{L}_1\mathbf{f}_1 - \mathbf{L}_0\mathbf{f}_1 \ ) + (\mathbf{L}_0\mathbf{f}_1 - \mathbf{L}_0\mathbf{f}_0 \ ) \\
&= (\mathbf{L}_0\mathbf{f}_1 - \mathbf{L}_0\mathbf{f}_0 \ ) + (\ \mathbf{L}_1\mathbf{f}_1 - \mathbf{L}_0\mathbf{f}_1 \ ) \\
&= \mathbf{L}_0(\Delta \mathbf{f}) + (\Delta \mathbf{L})\mathbf{f}_1
\end{aligned}
$$

Use the Fisher Index: average

Output $\mathbf{x} = \mathbf{Lf}$, the change in output: $\mathbf{x}_1 - \mathbf{x}_0$

We now have two answers! This is the non-uniqueness problem

$$\mathbf{x}_1 - \mathbf{x}_0 = \mathbf{L}_1(\Delta\,\mathbf{f}) + (\Delta\mathbf{L})\mathbf{f}_0$$
$$= \mathbf{L}_0(\Delta\,\mathbf{f}) + (\Delta\mathbf{L})\mathbf{f}_1$$

Solution: take the average

$$\mathbf{x}_1 - \mathbf{x}_0 = 0.5(\,\mathbf{L}_1 + \mathbf{L}_0\,)(\Delta\,\mathbf{f}) + 0.5(\Delta\mathbf{L})(\,\mathbf{f}_1 + \mathbf{f}_0\,)$$

Alternatives schemes

Output $\mathbf{x} = \mathbf{Lf}$, the change in output: $\mathbf{x}_1 - \mathbf{x}_0$

If you don't like different weights, an alternative is:

$$\begin{aligned}\mathbf{x}_1 - \mathbf{x}_0 &= \mathbf{L}_1(\Delta\mathbf{f}) + (\Delta\mathbf{L})\mathbf{f}_1 - (\Delta\mathbf{L})(\Delta\mathbf{f}) \\ &= \mathbf{L}_0(\Delta\mathbf{f}) + (\Delta\mathbf{L})\mathbf{f}_0 + (\Delta\mathbf{L})(\Delta\mathbf{f})\end{aligned}$$

but it includes interaction terms

in this simplest case (with two components) an interpretation can be given

when there are more components:

- the number of interaction terms increases rapidly
- interpretation becomes blurry

Expanding the SDA: More components

A less simple example contains three components
For example GDP = **vLf**
(with **v** the *row* vector of value added coefficients)

$\text{GDP}_1 - \text{GDP}_0 = \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 - \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0$

In deriving the decomposition form, let us work from left to right
i.e., first change **v**, then change **L** and finally change **f**

$$
\begin{aligned}
\text{GDP}_1 - \text{GDP}_0 &= \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 - \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0 \\
&= \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 - \mathbf{v}_0\mathbf{L}_1\mathbf{f}_1 + \mathbf{v}_0\mathbf{L}_1\mathbf{f}_1 - \mathbf{v}_0\mathbf{L}_0\mathbf{f}_1 + \mathbf{v}_0\mathbf{L}_0\mathbf{f}_1 - \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0 \\
&= (\Delta\mathbf{v})\mathbf{L}_1\mathbf{f}_1 + \mathbf{v}_0(\Delta\mathbf{L})\mathbf{f}_1 + \mathbf{v}_0\mathbf{L}_0(\Delta\mathbf{f})
\end{aligned}
$$

We have termed this: polar(L→R)

Expanding… continued for the polar

$GDP_1 – GDP_0 = \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 – \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0$

Polar(L→R):

$GDP_1 – GDP_0 = (\Delta\mathbf{v})\mathbf{L}_1\mathbf{f}_1 + \mathbf{v}_0(\Delta\mathbf{L})\mathbf{f}_1 + \mathbf{v}_0\mathbf{L}_0(\Delta\mathbf{f})$

This suggests that we also have a polar(R→L)

work from right to left

i.e. first change **f**, then change **L** and finally change **v**

$$
\begin{aligned}
GDP_1 – GDP_0 &= \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 – \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0 \\
&= \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 – \mathbf{v}_1\mathbf{L}_1\mathbf{f}_0 + \mathbf{v}_1\mathbf{L}_1\mathbf{f}_0 – \mathbf{v}_1\mathbf{L}_0\mathbf{f}_0 + \mathbf{v}_1\mathbf{L}_0\mathbf{f}_0 – \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0 \\
&= \mathbf{v}_1\mathbf{L}_1 (\Delta\mathbf{f}) \qquad + \mathbf{v}_1(\Delta\mathbf{L})\mathbf{f}_0 \qquad + (\Delta\mathbf{v})\, \mathbf{L}_0\mathbf{f}_0
\end{aligned}
$$

Use the Fisher Index: Averaging again

$GDP_1 – GDP_0 = \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 – \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0$

Polar(L→R):

$GDP_1 – GDP_0 = (\Delta\mathbf{v})\mathbf{L}_1\mathbf{f}_1 + \mathbf{v}_0(\Delta\mathbf{L})\mathbf{f}_1 + \mathbf{v}_0\mathbf{L}_0(\Delta\mathbf{f})$

Polar(R→L):

$GDP_1 – GDP_0 = (\Delta\mathbf{v})\ \mathbf{L}_0\mathbf{f}_0 + \mathbf{v}_1(\Delta\mathbf{L})\mathbf{f}_0 + \mathbf{v}_1\mathbf{L}_1\ (\Delta\mathbf{f})$

Solution: take the average

$$
\begin{aligned}
GDP_1 – GDP_0 = \quad & 0.5[\ (\Delta\mathbf{v})\mathbf{L}_1\mathbf{f}_1 + (\Delta\mathbf{v})\ \mathbf{L}_0\mathbf{f}_0\ ] \\
& + 0.5[\ \mathbf{v}_0(\Delta\mathbf{L})\mathbf{f}_1 + \mathbf{v}_1(\Delta\mathbf{L})\mathbf{f}_0\ ] \\
& + 0.5[\ \mathbf{v}_0\mathbf{L}_0(\Delta\mathbf{f}) + \mathbf{v}_1\mathbf{L}_1\ (\Delta\mathbf{f})\ ]
\end{aligned}
$$

The General SDA Scheme?

$\text{GDP}_1 - \text{GDP}_0 = \mathbf{v}_1\mathbf{L}_1\mathbf{f}_1 - \mathbf{v}_0\mathbf{L}_0\mathbf{f}_0$

1. Polar(L→R)
2. Polar(R→L)
3. Take the average

This is a "strategy" that always works, no matter how complex the form is

matrix = ABCDEFGHIJKLMNOPQRSTUVWXYZ

The strategy works straightforwardly
Try this at home!
But *don't* send me the results!!!

The General SDA Scheme?

Unfortunately, life is not that simple!

GDP = **vLf**

Polar(L→R): **v** → **L** → **f**
Polar(R→L): **f** → **L** → **v**

But why not:
L → **v** → **f** or **L** → **f** → **v** or **v** → **f** → **L** or **f** → **v** → **L**

Polars are convenient but not more plausible than any other form(it is not the case that one change takes place before the next)

<u>All six possible forms are equivalent</u>

Unfortunately, life is not that simple!

If *n* components, there are *n*! of equivalent decomposition forms. The average of all is the answer, due to equivalence.

So…if 14 components > 87 billion different forms!

Yikes! Life can be a bitch.

Fortunately, average of two polars ≈ average of all *n*! forms

Life can be made simper if you don’t always worry the details.

The General SDA Scheme?

- We have only considered ***additive*** decompositions

  $\mathrm{GDP}_1 - \mathrm{GDP}_0 = (\Delta\mathbf{v})\mathbf{L}_1\mathbf{f}_1 + \mathbf{v}_0(\Delta\mathbf{L})\mathbf{f}_1 + \mathbf{v}_0\mathbf{L}_0(\Delta\mathbf{f})$
  67 = 13 + 42 + 12
  or as contributions: 100 = 19.4 + 62.7 + 17.9

- Some component's contribution may be > 100%
  67 = 13 + 72 – 18 (or 100 = 19.4 + 107.5 – 26.9)

- SDA can handle ratios too
  (i.e., growth instead of increases)

Multiplicative SDA

Consider the growth in total output: $\frac{\mathbf{ux}_1}{\mathbf{ux}_0}$

$$\frac{\mathbf{ux}_1}{\mathbf{ux}_0} = \frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_0} = \frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_1} \times \frac{\mathbf{uL}_0\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_0}$$

This polar(L→R)

$\frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_1}$ can be interpreted as the “Paasche L-index” (end year weights)

$\frac{\mathbf{uL}_0\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_0}$ then is the “Laspeyres f-index” (initial year weights)

For example: 1.96 = 1.2 × 1.6
Interpretation:

final demand changes only would have caused an output growth of 60%
changes in L only a growth of 20%, taken together 92%

Multiplicative SDA

Polar(L→R):

$$\frac{\mathbf{ux}_1}{\mathbf{ux}_0} = \frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_0} = \frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_1} \times \frac{\mathbf{uL}_0\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_0}$$

Paasche L × Laspeyres f

Alternatively: polar(R→L)

$$\frac{\mathbf{ux}_1}{\mathbf{ux}_0} = \frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_0} = \frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_1\mathbf{f}_0} \times \frac{\mathbf{uL}_1\mathbf{f}_0}{\mathbf{uL}_0\mathbf{f}_0}$$

Paasche f × Laspeyres L

Multiplicative SDA

Solution: take the (geometric) average of the polars

$$\frac{\mathbf{ux}_1}{\mathbf{ux}_0} = \sqrt{\frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_1} \times \frac{\mathbf{uL}_1\mathbf{f}_0}{\mathbf{uL}_0\mathbf{f}_0}}\ \sqrt{\frac{\mathbf{uL}_0\mathbf{f}_1}{\mathbf{uL}_0\mathbf{f}_0} \times \frac{\mathbf{uL}_1\mathbf{f}_1}{\mathbf{uL}_1\mathbf{f}_0}}$$

$$= \sqrt{\text{Paasche L} \times \text{Laspeyres L}}\ \sqrt{\text{Laspeyres f} \times \text{Paasche f}}$$

= Fisher L × Fisher f

Q1: What drives growth in global GHG emissions?

Growth in Global GHG Emissions

Latest years, growth in the emissions from the production of traded goods (i.e. growth in the emission transfers through international trade):

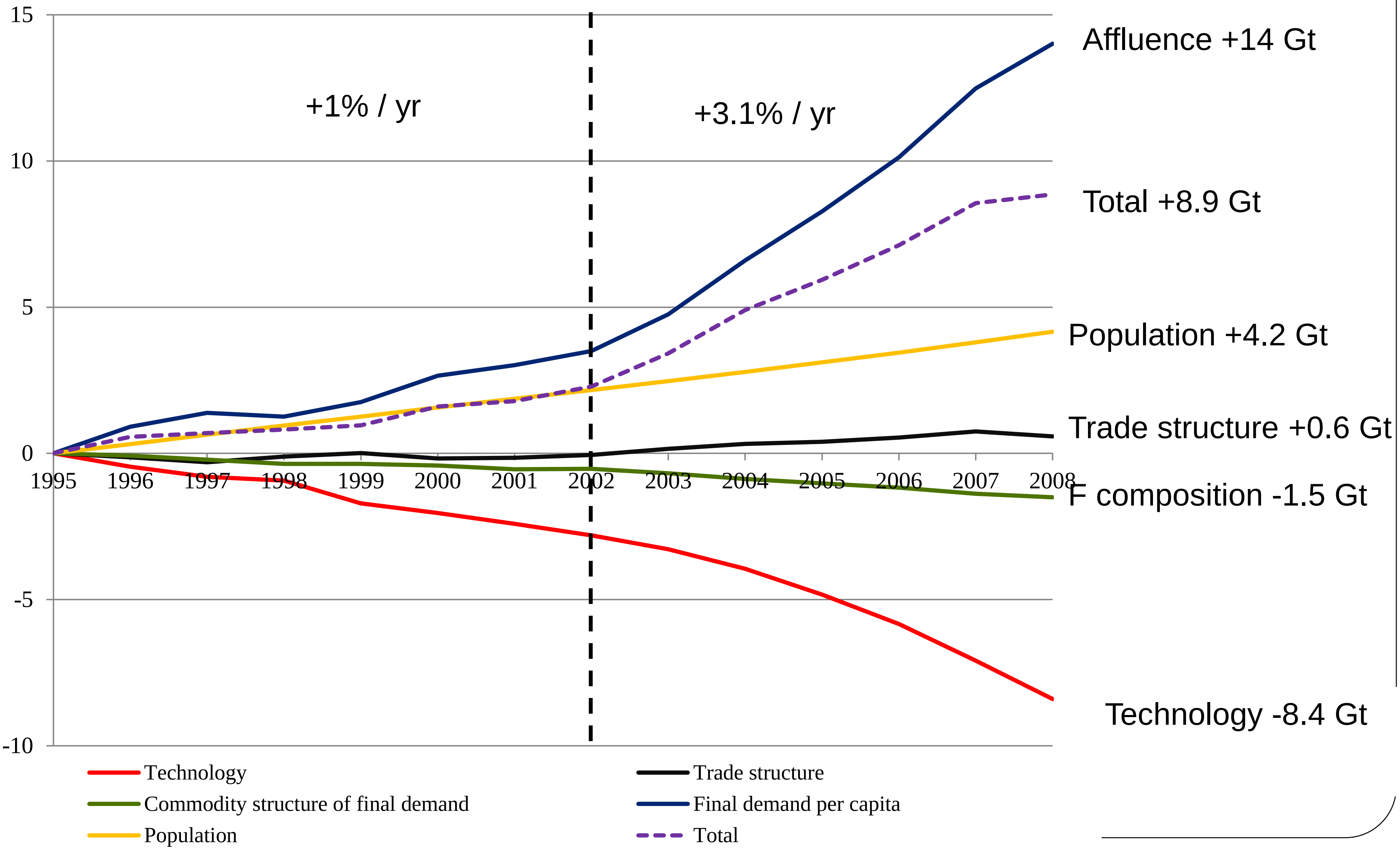
- Peters et al. (2011), GTAP: CO2 embedded in trade increased from 20% in 1990 to 26% in 2008
- Arto et al. (2012), WIOD: GHG embedded in trade increased from 19% in 1995 to 27% in 2008

Growth in Global GHG Emissions

Trade **could** have enabled increase in GHG emissions by relocating CO_2-intensive industries to countries with lower environmental stringency and **higher emission intensities** (Pollution Haven Hypothesis, Exporting Pollution, & Carbon Leakage)

Q2: Have trade changes contributed to the growth in global GHG?

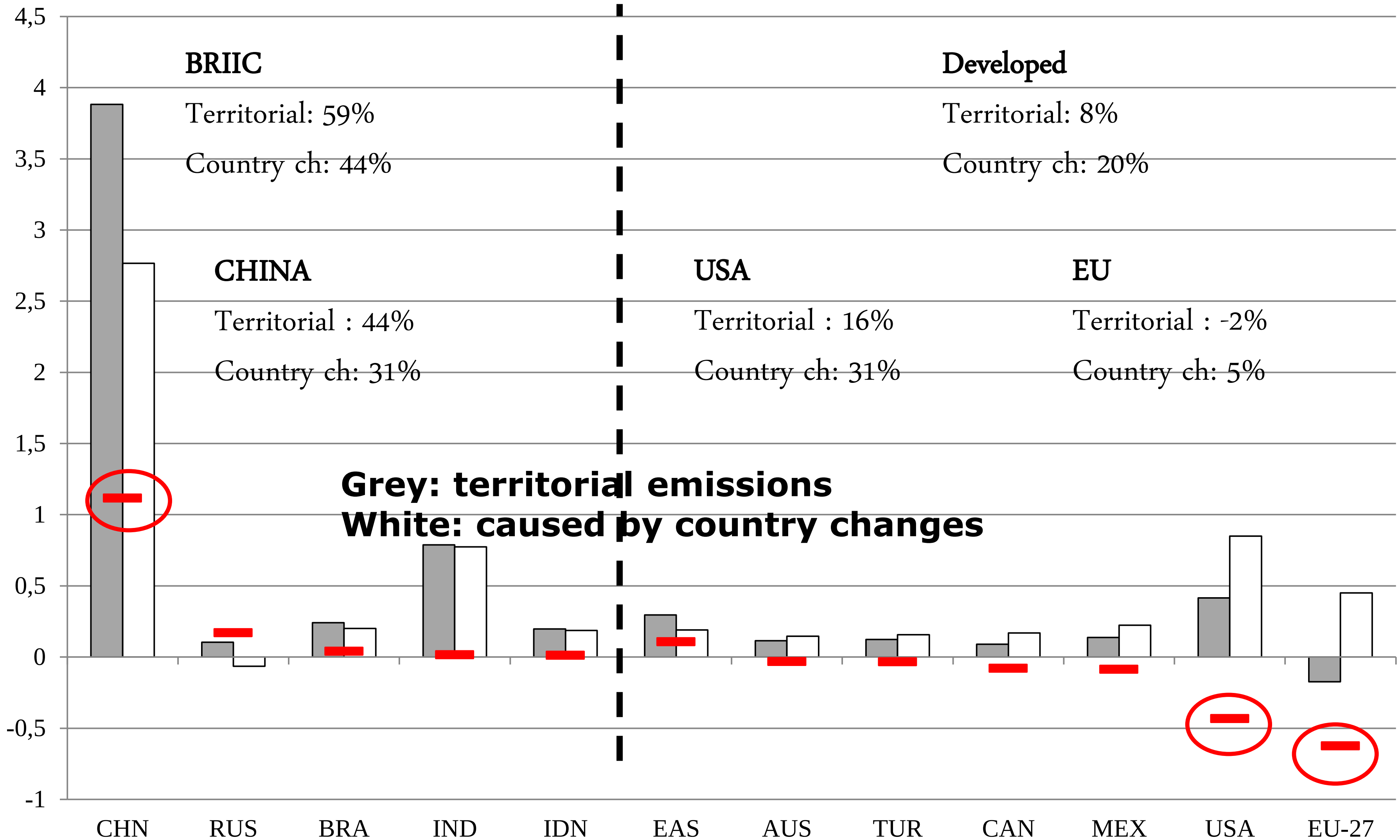
1995: 30.45 Gt,   2008: 39.31 GT



	Technology (1)	Trade structure (2)	F composition (3)	Affluence (4)	Population (5)	Total (6 = 1 to 5)	
BRIC	**-3,560**	**89**	**-825**	**7,255**	**904**	**3,863**	**44%**
BRA	-42	15	-29	136	121	201	2%
CHN	-2,526	412	-405	4,881	404	2,766	31%
IDN	-39	-7	26	127	80	187	2%
IND	-478	-11	-145	1,053	354	773	9%
RUS	-475	-320	-272	1,058	-55	-64	-1%
Developed	**-2,771**	**120**	**-947**	**3,893**	**1,511**	**1,806**	**20%**
AUS	-4	-46	-29	140	85	146	2%
CAN	-169	68	-7	198	80	170	2%
EAS	-274	180	-146	344	85	189	2%
EU-27	-1,374	130	-166	1,577	284	451	5%
USA	-950	-212	-599	1,634	977	850	10%
MEX	-70	5	-16	205	98	223	3%
TUR	-97	28	-4	167	64	157	2%
RoW	**-1,900**	**341**	**294**	**2,494**	**1,580**	**2,809**	**32%**
World	**-8,399**	**582**	**-1,498**	**14,014**	**4,158**	**8,858**	

Regions: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; EAS: East Asia (Japan, South Korea, Taiwan); EU-27: European Union 27 Member States; IND: India; IDN: Indonesia; MEX: Mexico; RUS: Russia; TUR: Turkey; GBR: United Kingdom; USA: United States of America; RoW: Rest of the World.

Change in global emissions by country according to the producer and shared responsibilities (Gt)



The Value of Supply Chain and Carbon Emissions in China

Trade in tasks

factoryless goods

Trade in Value-added

The 2nd great unbundlings

Made in the world

Assembled in China, designed in California

Smile curves

Outsourcing

Offshoring

value-chain

Vertical specialization

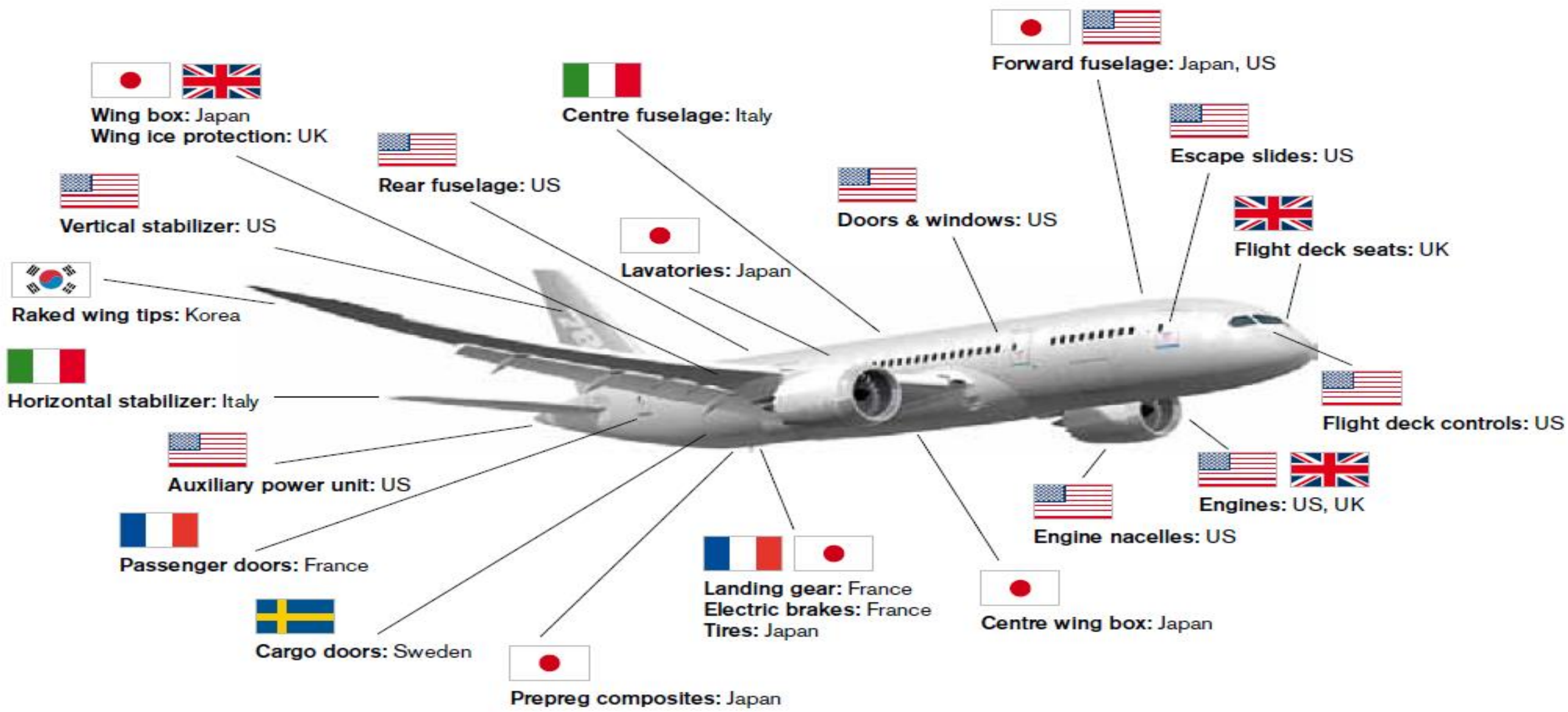
Fragmentation production

Intra-firm trade

transfer pricing

Fragmentation production in global supply chains

The fragmentation of production: The example of the Boeing 787 Dreamliner



Tools/Software: France
Navigation: US
Pilot control system: US
Wiring: France

Final assembly: Boeing Commercial Airplanes, US

Source: Meng and Miroudot (2011).

Made in USA

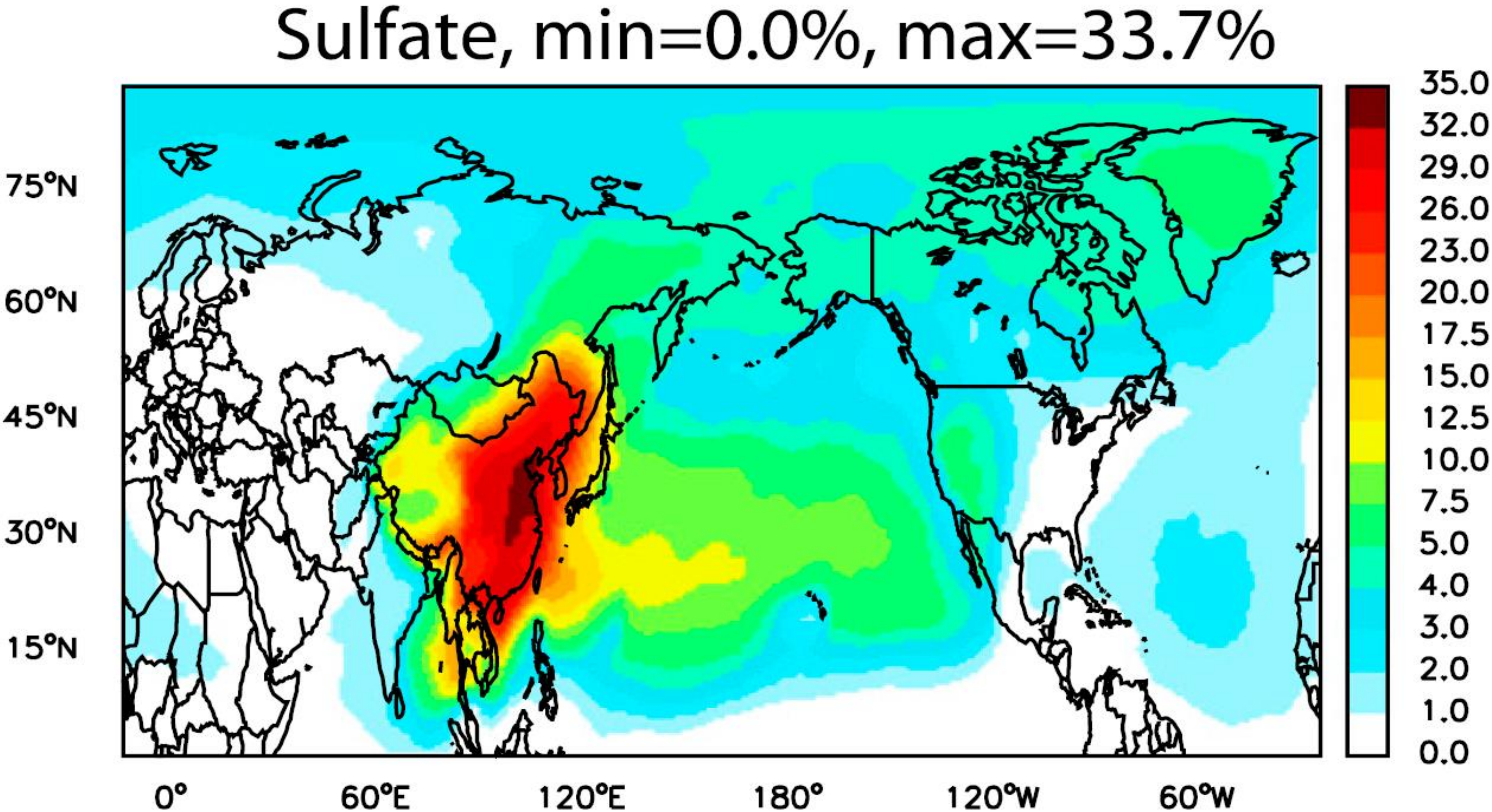
↓

Made in the World

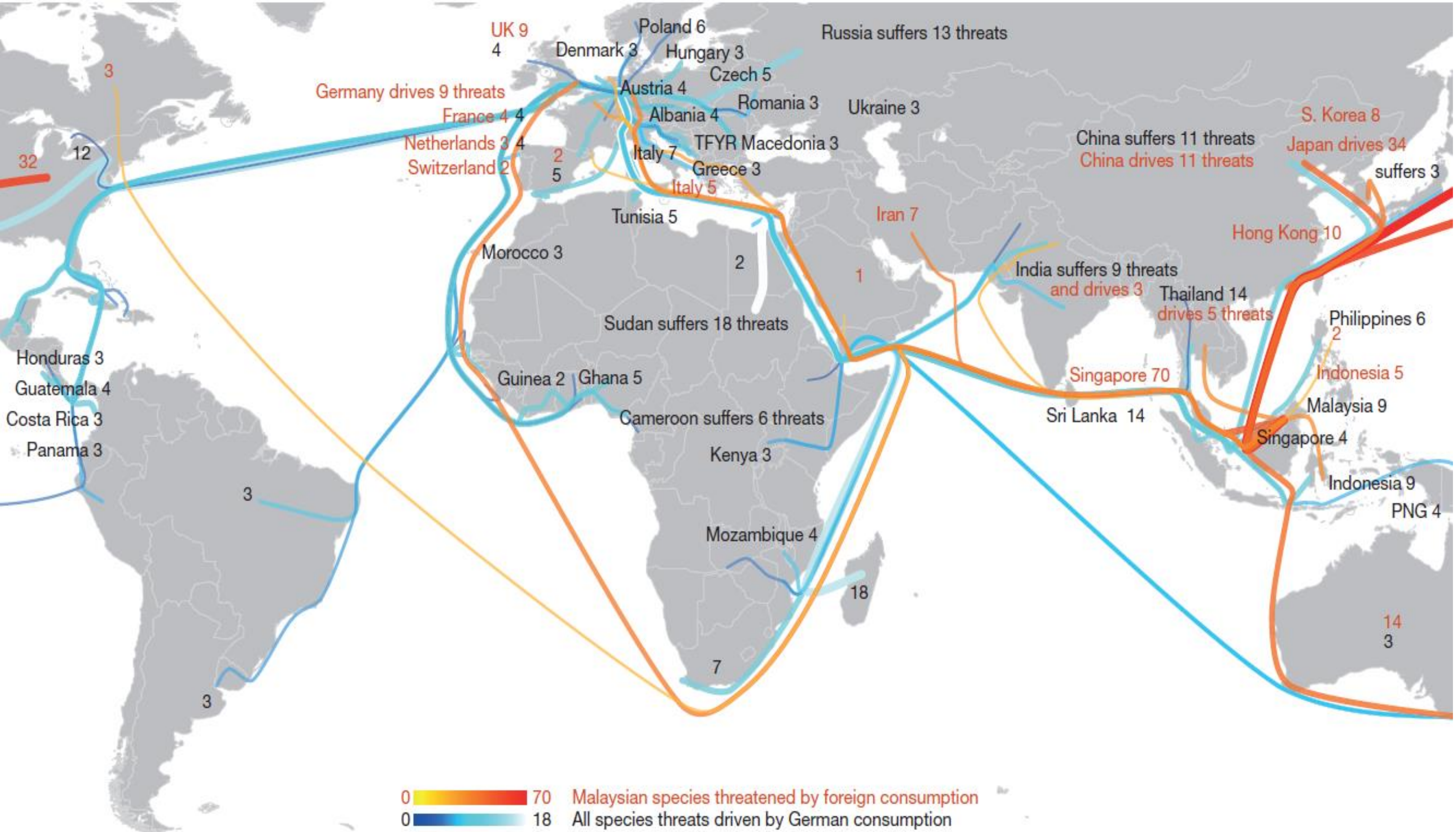
Value, income, job creation

v.s.

Emission (pollution) creation



Lin et al. (*PNAS*, 2013) show 12-24% of sulfate concentrations over western US from export-related pollution from China.



Lenzen et al. (*Nature*, 2012) found **30%** of global species threatened by **international trade**.

Traditional measures of trade in emissions:

…Ahmad and Wyckoff, 2003; Lenzen et al., 2004; Peters and Hertwich, 2004; Peters, 2008; Peters and Hertwich, 2008a,b, Peters et al 2011, Tukker and Dietzenbacher, 2013, Kanemoto et al 2012,14…

"emission trade", "emission export", "trade in emissions", "emissions in trade", "embodied emission", "footprint", "international transfer of emissions", "production-based emissions", "consumption-based emissions", "carbon leakages"

⇩

"A man with a watch knows what time it is.
A man with two watches is never sure."

⇩

New measures for supply chains:

…WTO-IDE(2011), OECD-WTO (2013), Koopman, Wang and Wei (2014, AER-KWW), Wang, Wei, Zhu (2013), Meng, Wang, Koopman (2014)…

⇩

A new and consistent accounting system

to properly trace emissions across supply chains by stage, arc, path…

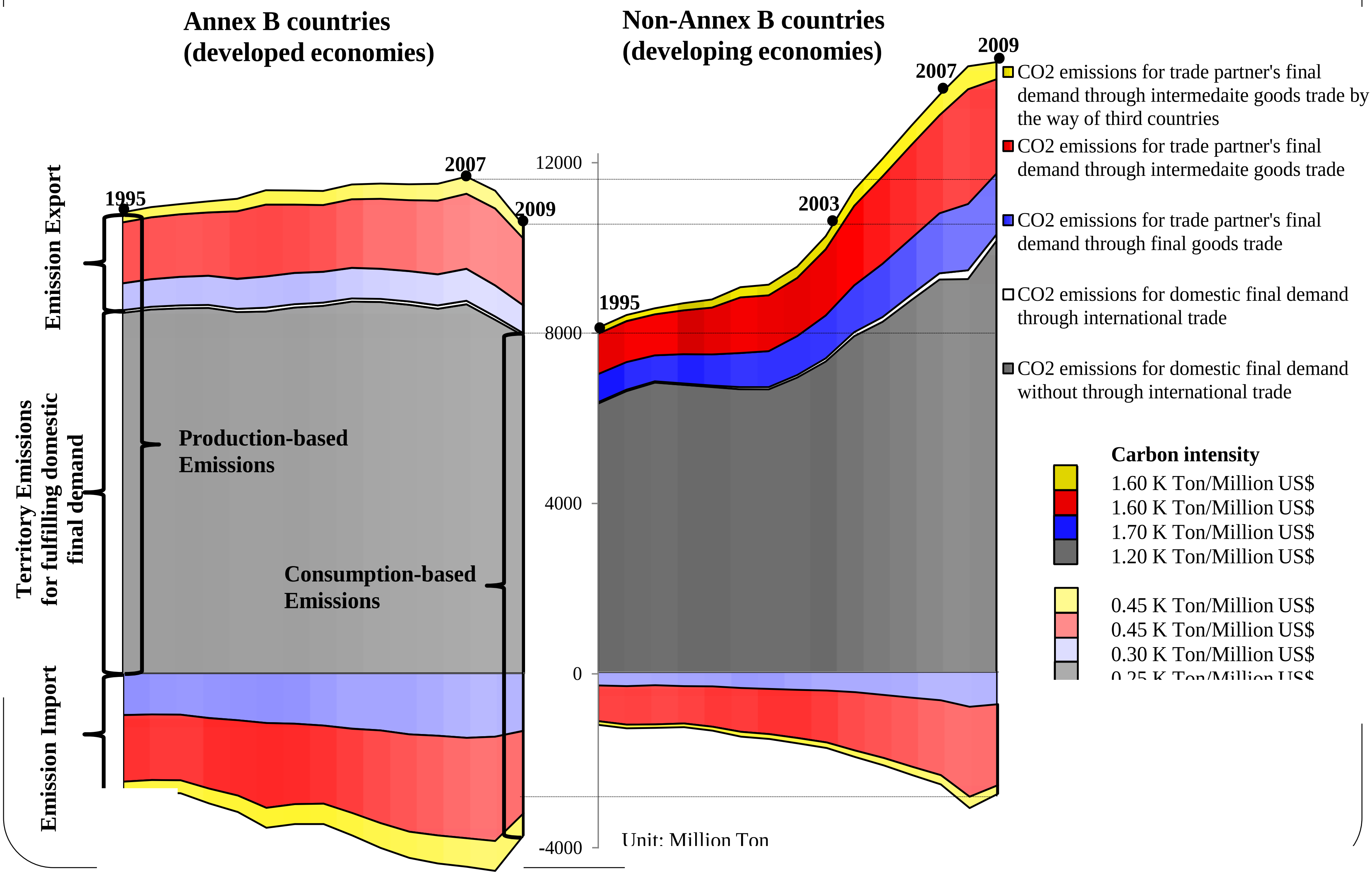
Supply-chain based Emission Accounting Framework

1) Emissions generated by a country's specific industry is for its own and other countries' consumption through various supply-chain routes →(From upstream to downstream)

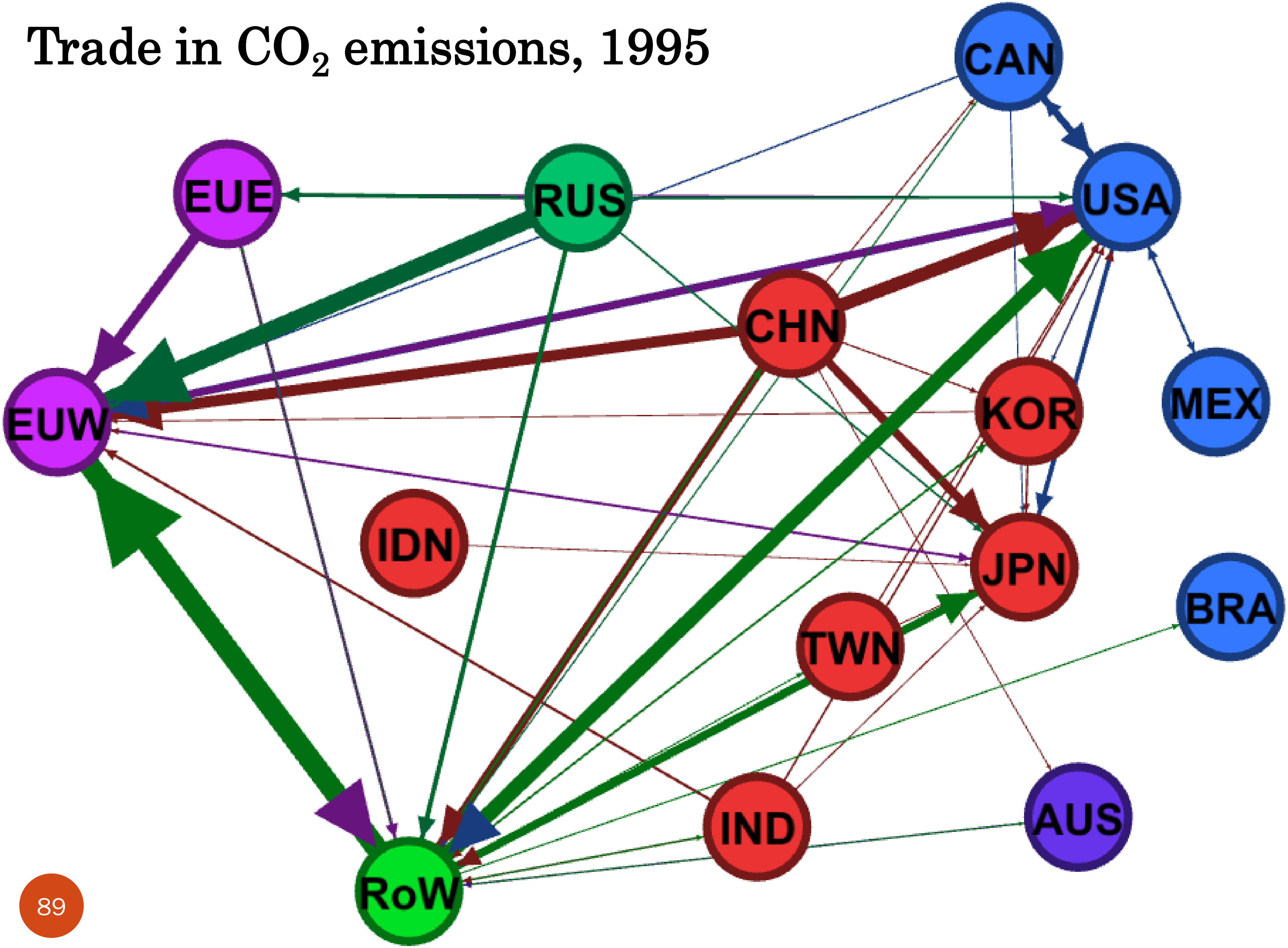
2) How does a country's production of exports induce emissions in other countries along supply chains?
→ (From downstream to upstream)

3) What amounts of emissions have been generated to create one unit of GDP in each stage of production-sharing via various supply-chain routes? (Potential environmental costs)

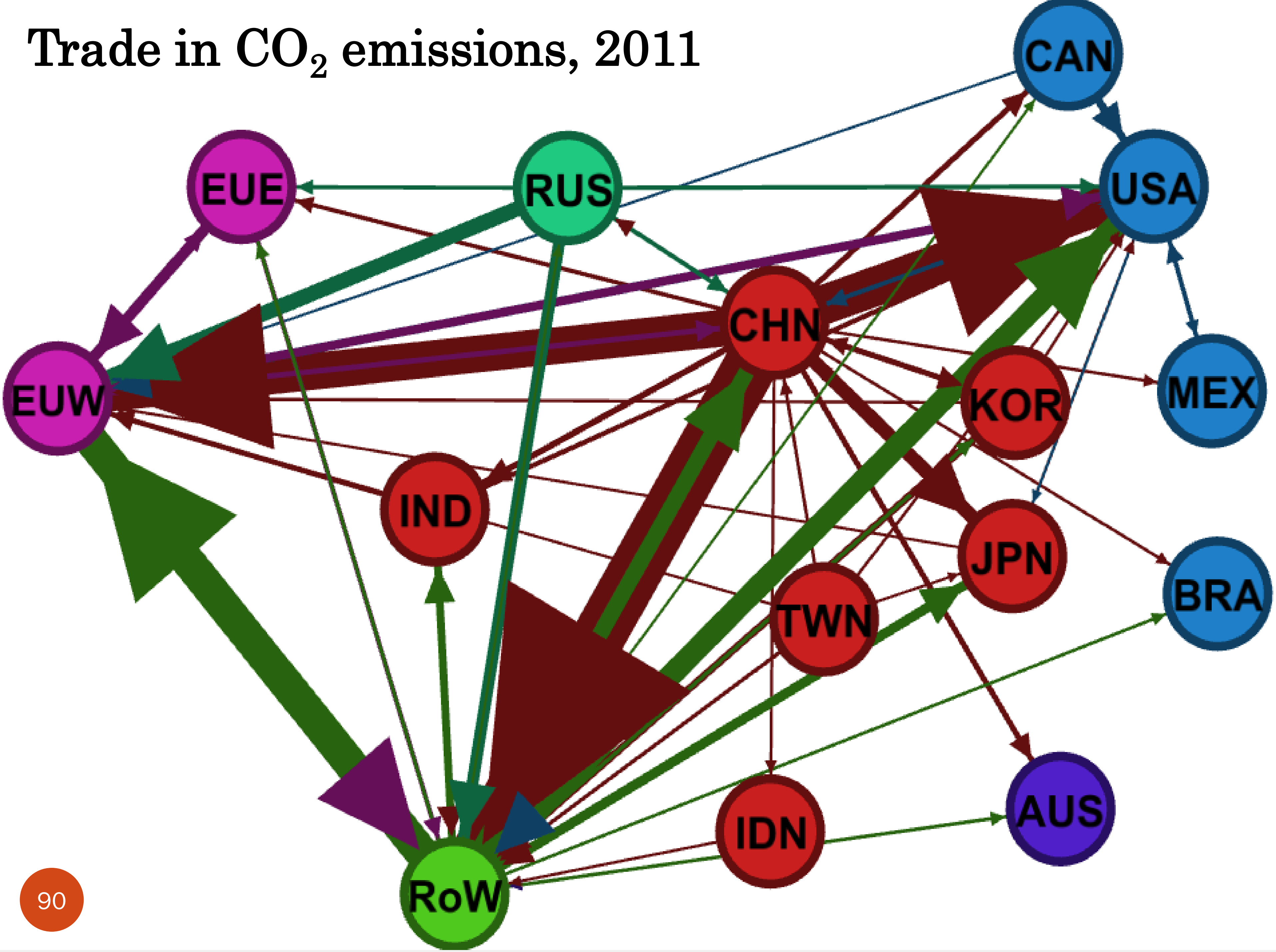
Supply-chain based emission accounting framework:
Production vs. consumption-based emissions and emission transfer

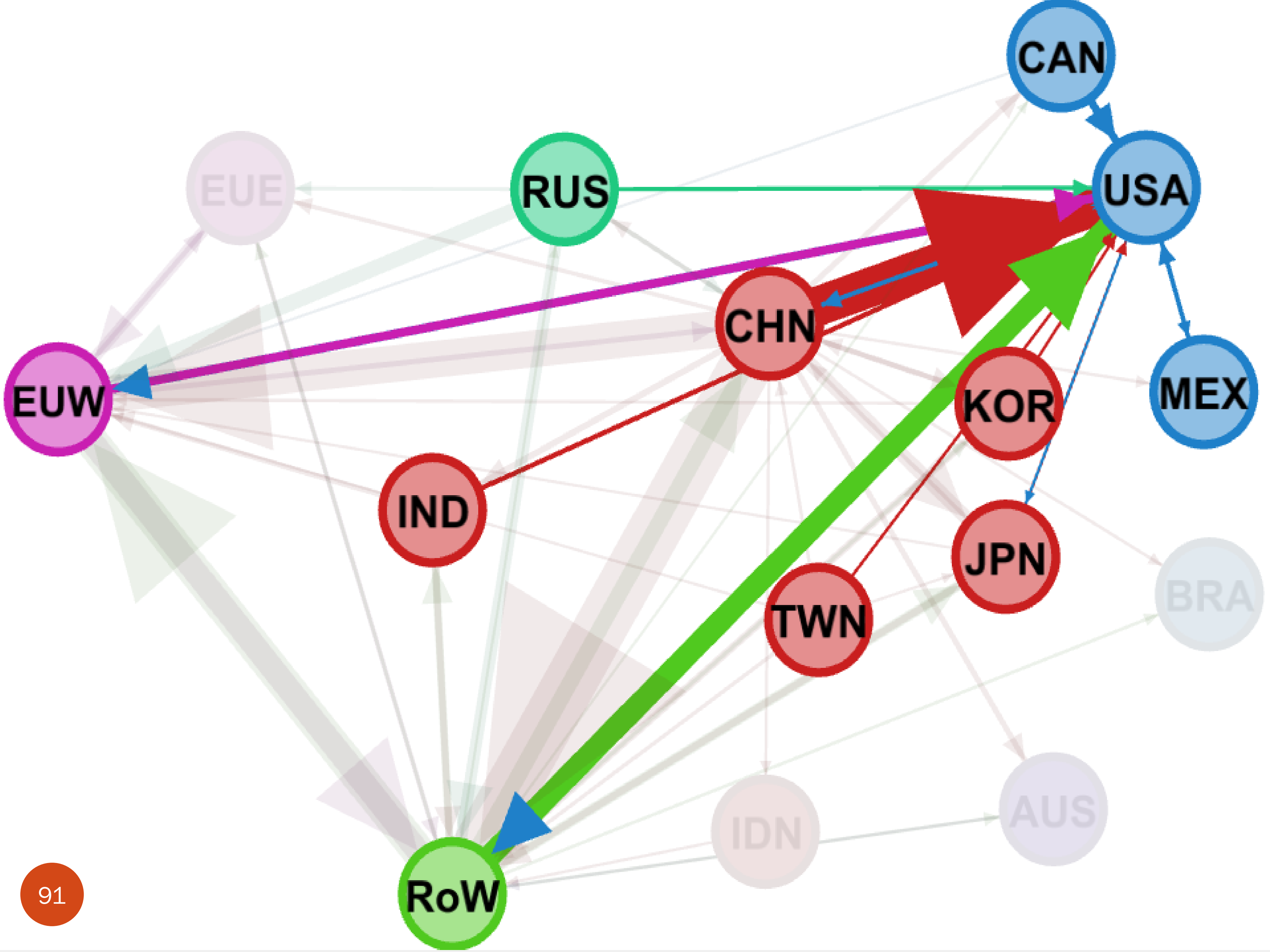


Trade in CO_2 emissions, 1995



Trade in CO_2 emissions, 2011

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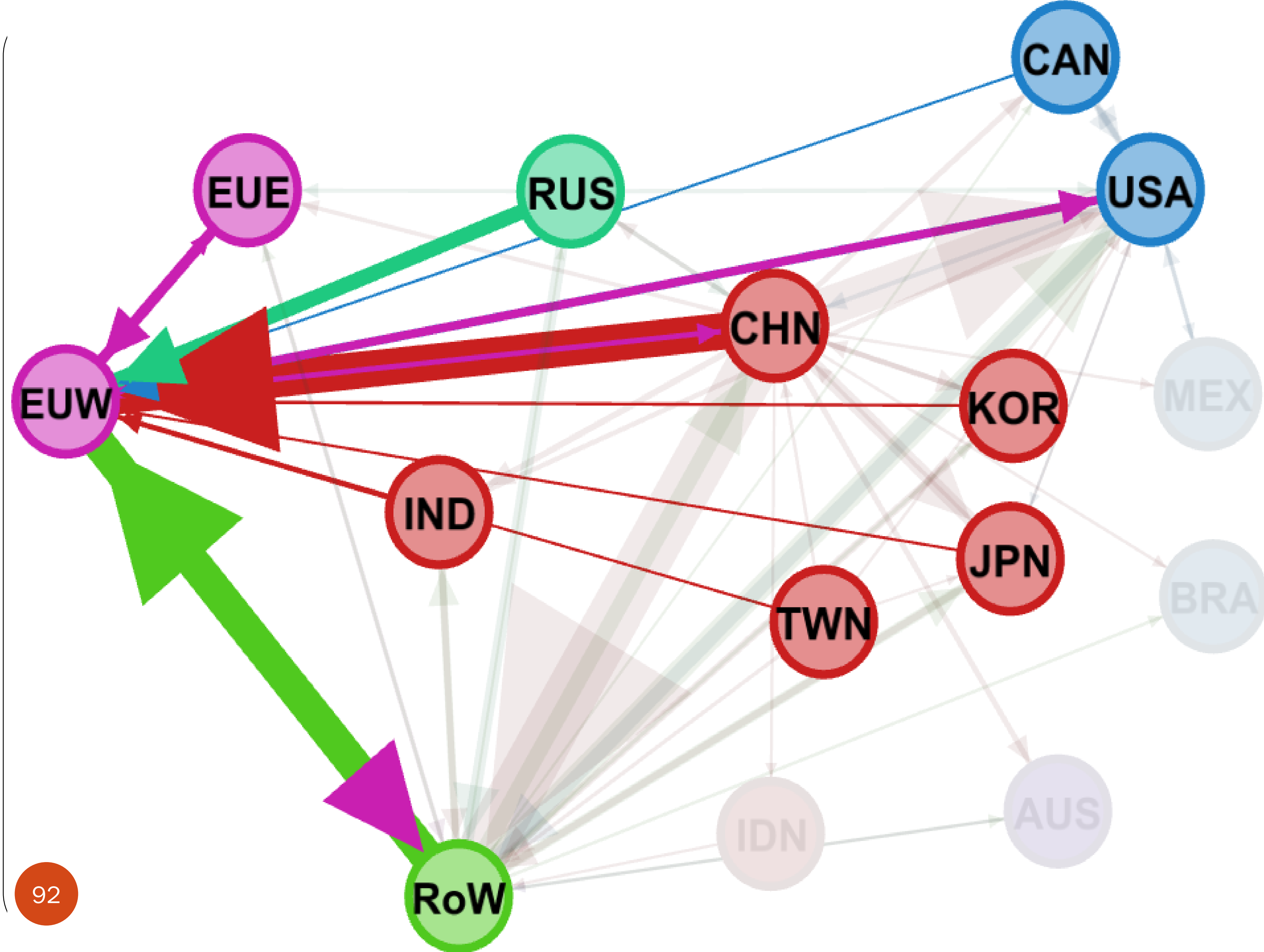
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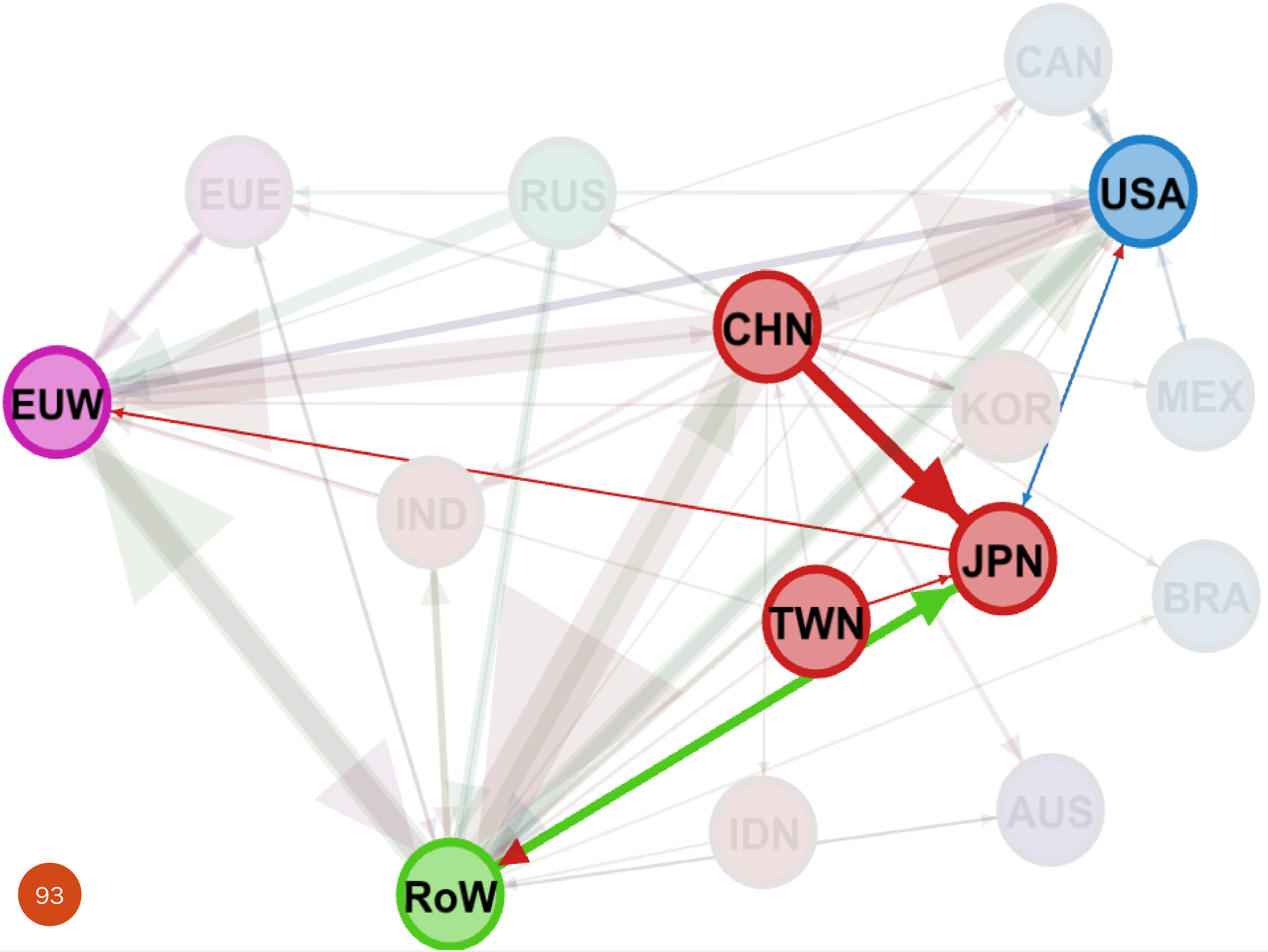
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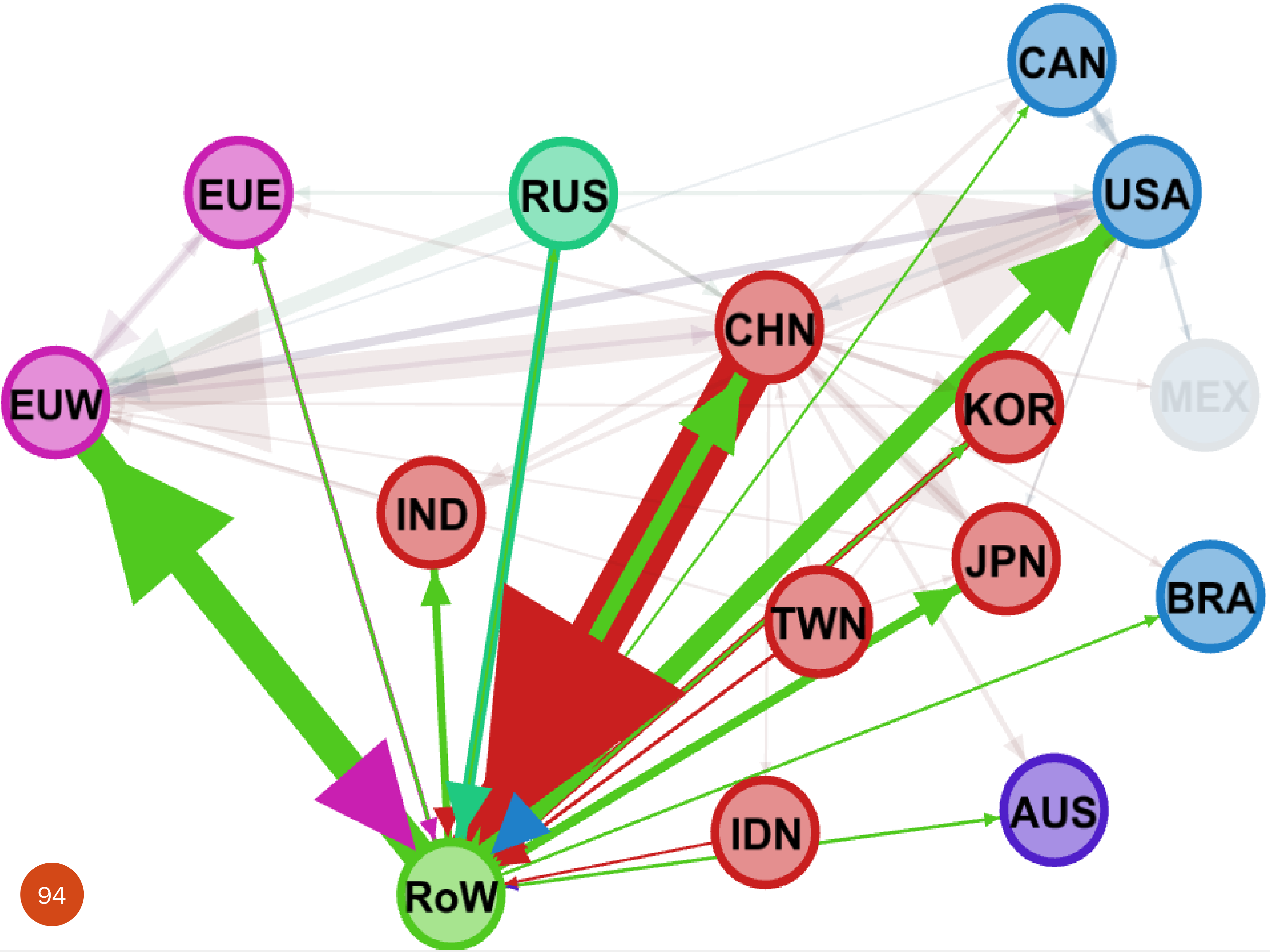
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Policy implications

- Actions must be taken to retard the rapid increasing carbon leakage among developing economies. The south-south cooperation is essential and urgent!

- To first help developing countries to set an appropriate peaking time and level in terms of the current self-responsibility-based emissions should be a constructive way.

- The international consensus on environment related international standard (regulation) targeting on multinationals' activities can prevent developing economies from "race to the bottom" game or falling into the "pollution haven" situation.

Toward Frameshifting:
A discussion of advances in econometric+IO modeling

Motivations for EC+IO Models

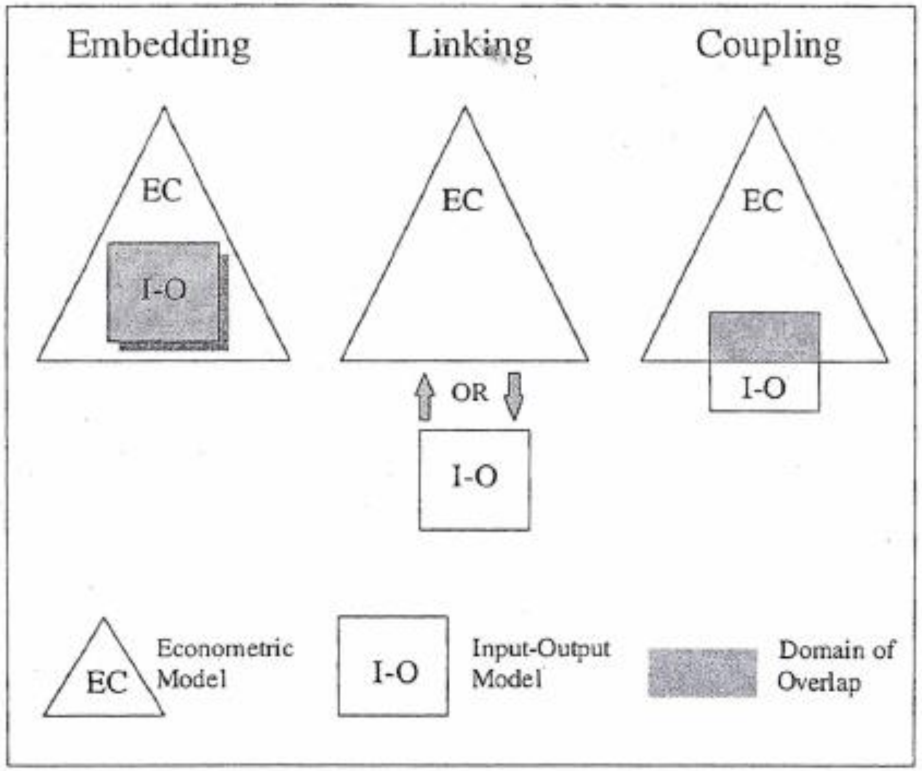
- Restrictive characteristics of the parent models

Characteristic	IO	EC	EC+IO
Dynamic		√	√
Disaggregate	√		√
Price Responsive		√	√
Impact Analysis	√	√	√
Demand Driven	√	√	√
Forecasting		√	√
Inferential		√	?
Multiregional	√	√	?

- Conjoins systemic GE perspective IO with historical dynamics of EC
- Restrictive determinism of IO can potentially be moderated with parameter stochastics of EC
- Model integration forces building of a better-grounded regional I-O table

Rey's Integration Strategies

- **Embedded**: IO fully in EC
- **Linked**: On or a few IO components feeds into EC or vice versa
- **Coupled**: Many areas of overlap like embedding but independence maintained as in linked.



Implications of more or less integration

- ↑ integration => Loss of IO disaggregation
  - A direct effects linking of IO into EC is best for maintaining IO detail
  - To keep detail, heroic assumptions about dynamics of industry mix within EC sectors must be made
- Greater lets interconnections in I-O technology affect EC
  - GE balance of VA and FD?
  - Compensation-VA-gross output relationships
- EC prices affect IO relationships
  - Overall labor market regulated via relative wage rates
  - Relative regional PPI and CPI affects export import volumes

Concern for EC in the long run:
How can EC+IO help?

- Technology change in EC always an issue
- Relationships between VA and gross output by sector modified using production function (translog, Cobb-Douglas) and prices
- Direct relationship between HH consumption & gross output also add pressure
- Variations in HH consumption derived via cohort change (income groups of SAM)
- Trends in gov't expenditure item shares?
- RAS variant can be used to modify IO technology relationships subject to EC margins

EC modifiers of IO in SAMNJ

- Supersector GDP, employment, wage rates, and GDP deflators
- State and federal operations expenditures
- State and federal capital expenditures
- Unemployment and rate
- Personal and disposable income
- Dividends
- Total wage and salary income
- Transfer payments to HH
- US consumer spending in 16 categories
- 3 CPI categories
- Gross output is updated using growth rate of industry W&S income
- Non-value-added production values updated using translog of intermediate production and imports/inflows from WIOD.

Layout of SAMNJ 2010

	Institutions (4)	Transfers (2)	Taxes & Subsidies (6)	Gross Capital Formation (4)	Savings (1)	Primary Factors(2)	Industries (416)	Foreign Sectors (2)
Institutions	Transfers among institutions	Redistribution unemployment benefits and dividends	Redistribution of tax revenues among the institutional sectors			Labor and capital income		
Transfers	Unemployment benefits and dividends payments							
Taxes & subsidies	Income taxes and subsidies payments						Contributions, taxes on production, sale taxes and tariffs	
Gross Capital Formation					Redistribution of savings			
Savings	Public and private savings							Foreign savings
Primary factors							Labor and capital income	Adjustments for residence
Productive sectors	Public and private consumption		Subsidies on production	Investment and Stocks variation			Intermediate matrix	Exports
Foreign sector							Imports	

Bi-directional feedback

- RAS the SAM to ensure balance, holding knowns fixed
- SAM used to add factor EC
- Forecast re-estimated using revised future as history

The Product

- A GE-modified forecast
- A set of SAMs

- Can even develop CGE models for each year, given identical SAM format

Why the Interest?

- Need for longer-range tools to anticipate economic changes not within history and their affects
  - Climate change
    - Rising average temps
    - More precipitation or drought
    - Rising sea levels
    - Rising weather variation
      - Fast-rising electricity costs
      - More major storms
  - More trade agreements?
  - Long-run perspectives of fiscal instruments (PPPs)

Thanks for your attention!