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Unequal Pollution Flows: Brazil's Role in Global Emission Trade (1995–2018)

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Objective

- Investigates Brazil's position in global carbon flows by analyzing whether the country acts as a net exporter or importer of greenhouse gas (GHG) emissions in its trade with the Global North and the Global South from 1995 to 2018.

Motivation

- increasing interconnection of economies through trade and the fragmentation of global production chains
- transfer of emissions embedded in traded goods, amplifying the environmental dimension of international trade
- Brazil: reprimarization, marked by a rising share of primary commodities - East Asia
- should greenhouse gas emissions be attributed to the country where goods are produced, or to the country where they are ultimately consumed?

Theoretical framework

- Production-Based Emissions (PBE)
  - Assign responsibility to the country where emissions physically occur.
  - Basis for most international climate agreements (e.g., Kyoto, Paris).
- Consumption-Based Emissions (CBE)
  - Assign responsibility to the final consumer.
  - Includes emissions from imports and excludes those from exports.
  - Offers a broader picture of how emissions are redistributed via global trade.
- The Gap (PBE vs. CBE)
  - Reveals net emission transfers between countries.
  - Essential for evaluating climate justice and environmental interdependence

Theoretical Framework

- Pollution Haven Hypothesis (PHH)
  - Under free trade, pollution-intensive industries relocate from the Global North to the Global South.
  - Motivation: avoid stricter environmental regulations in developed countries.
  - Result: environmental burdens shift along global supply chains.
- Country Groups
  - Global North—typically comprising capital- and technology-intensive economies
  - Global South—often specialized in intermediate and resource-based goods

Methodology

- Starting point: traditional input-output model, such as:

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{f}\boldsymbol{x} = \left(\boldsymbol{I} - \boldsymbol{A}\right)^{-1}\boldsymbol{f}$$

But we disagregate the final demand and the production for regions:

Methodology

- $$\begin{pmatrix} \boldsymbol{x}^{B} \\ \boldsymbol{x}^{S} \\ \boldsymbol{x}^{N} \\ \boldsymbol{x}^{R} \end{pmatrix} = \begin{pmatrix} \boldsymbol{A}^{BB} & \boldsymbol{A}^{BS} & \boldsymbol{A}^{BN} & \boldsymbol{A}^{BR} \\ \boldsymbol{A}^{SB} & \boldsymbol{A}^{SS} & \boldsymbol{A}^{SN} & \boldsymbol{A}^{SR} \\ \boldsymbol{A}^{NB} & \boldsymbol{A}^{NS} & \boldsymbol{A}^{NN} & \boldsymbol{A}^{NR} \\ \boldsymbol{A}^{RB} & \boldsymbol{A}^{RS} & \boldsymbol{A}^{RN} & \boldsymbol{A}^{RR} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}^{B} \\ \boldsymbol{x}^{S} \\ \boldsymbol{x}^{N} \\ \boldsymbol{x}^{R} \end{pmatrix} + \begin{pmatrix} \boldsymbol{f}^{BB} & \boldsymbol{f}^{BS} & \boldsymbol{f}^{BN} & \boldsymbol{f}^{BR} \\ \boldsymbol{f}^{SB} & \boldsymbol{f}^{SS} & \boldsymbol{f}^{SN} & \boldsymbol{f}^{SR} \\ \boldsymbol{f}^{NB} & \boldsymbol{f}^{NS} & \boldsymbol{f}^{NN} & \boldsymbol{f}^{NR} \\ \boldsymbol{f}^{RB} & \boldsymbol{f}^{RS} & \boldsymbol{f}^{RN} & \boldsymbol{f}^{RR} \end{pmatrix}$$
- where $\boldsymbol{x}^{r}$ is a 45×1 vector representing the total output of country r for each sector; $\boldsymbol{A}$ is the global direct input coefficient matrix that reflects the interconnections between different sectors of the economy, where $\boldsymbol{A}^{rp}$ is a 45×45 matrix denoting the intermediate input coefficient matrix. It indicates how many intermediate goods from country r are needed by country p to produce one monetary unit of output. In turn, $\boldsymbol{f}^{rp}$ is a 45×1 vector representing the final demand for products from country p by country r.

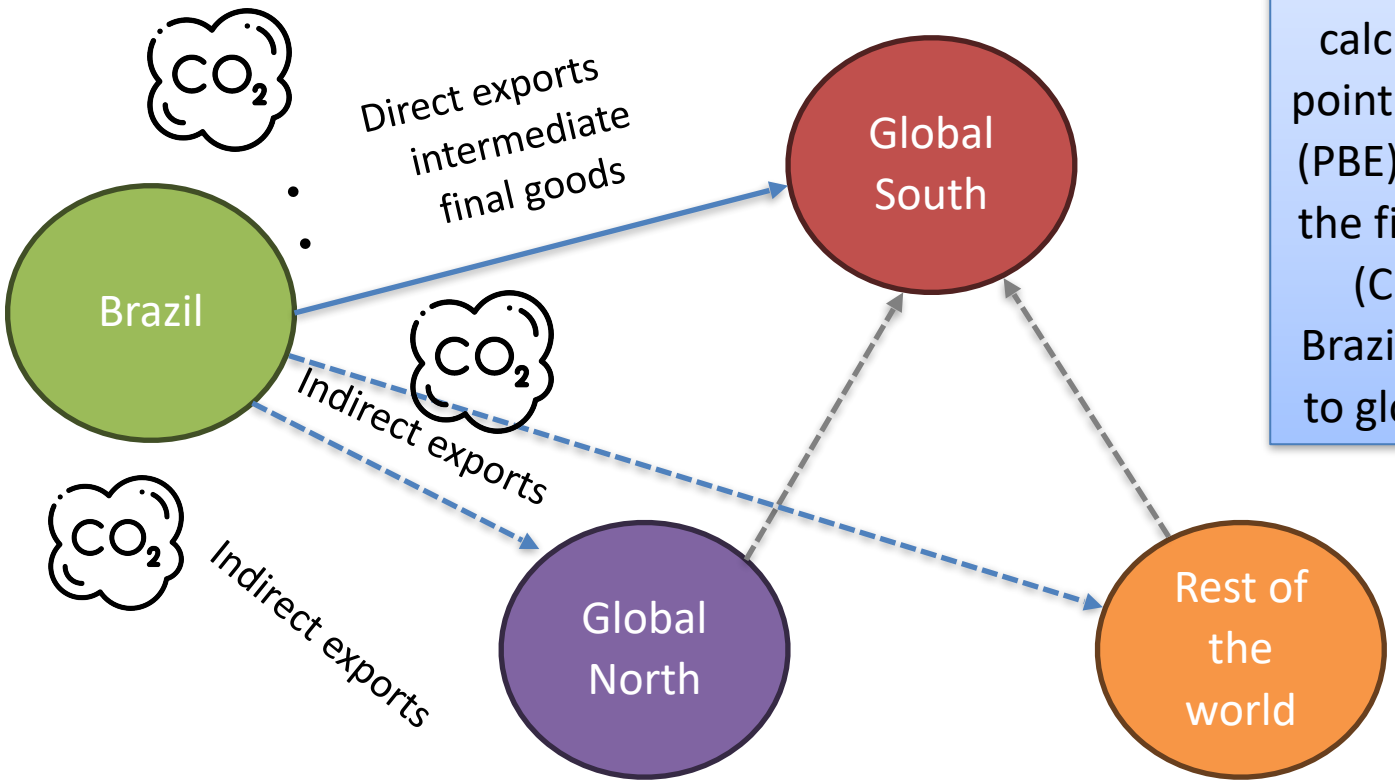
Methodology

- Brazil's exports to the Global South (FX_{BS}): all L^{**} elements must be set to 0 except for L^{B*}, and all F^{**} elements must be set to 0 except for F^{*S}.

$$FX_{BS} = \begin{pmatrix} L^{BB} & L^{BS} & L^{BN} & L^{BR} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} 0 & f^{BS} & 0 & 0 \\ 0 & f^{SS} & 0 & 0 \\ 0 & f^{NS} & 0 & 0 \\ 0 & f^{RS} & 0 & 0 \end{pmatrix} =$$

$$L^{BB}f^{BS} + L^{BS}f^{SS} + L^{BN}f^{NS} + L^{BR}f^{RS}$$

Pathways of Brazilian Exports to the Global South



Combined approach: Emissions are calculated at the point of production (PBE) but traced to the final consumer (CBE), linking Brazil's production to global demand.

Pathways of Brazilian Exports to the Global South

- Direct exports
  - final goods exports from Brazil (B) to the Global South (S) - $\boldsymbol{L^{BB} f^{BS}}$
  - Denotes direct intermediate goods exported from Brazil to the Global South (depending on S Leontief) - $\boldsymbol{L^{BS} f^{SS}}$.
- Indirect exports
  - intermediate exports: Sent first to the Global North (N) or Rest of the World (R) to produce goods that are going to be exported to the Global South (S) - $\boldsymbol{L^{BN} f^{NS} + L^{BR} f^{RS}}$.

Emission

- $\boldsymbol{\delta} = \left(\boldsymbol{\delta}^{\mathbf{B}}, \boldsymbol{\delta}^{\mathbf{R}}, \boldsymbol{\delta}^{\mathbf{N}}, \boldsymbol{\delta}^{\mathbf{R}}\right)$ be the carbon emission intensity vector, which represents the carbon emissions per unit of gross output for each country
- multiplication $\boldsymbol{\delta}^{\mathbf{B}}$ by $\boldsymbol{FX}_{\boldsymbol{BS}}$ to obtain the Brazilian emissions when it exports to the Global South:

$$\boldsymbol{CFX}_{\boldsymbol{BS}} = \boldsymbol{CFI}_{\boldsymbol{SB}} = \boldsymbol{\delta}^{\mathbf{B}} \boldsymbol{L}^{\boldsymbol{BB}} \boldsymbol{f}^{\boldsymbol{BS}} + \boldsymbol{\delta}^{\mathbf{B}} \boldsymbol{L}^{\boldsymbol{BS}} \boldsymbol{f}^{\boldsymbol{SS}} + \boldsymbol{\delta}^{\mathbf{B}} \boldsymbol{L}^{\boldsymbol{BN}} \boldsymbol{f}^{\boldsymbol{NS}} + \boldsymbol{\delta}^{\mathbf{B}} \boldsymbol{L}^{\boldsymbol{BR}}$$

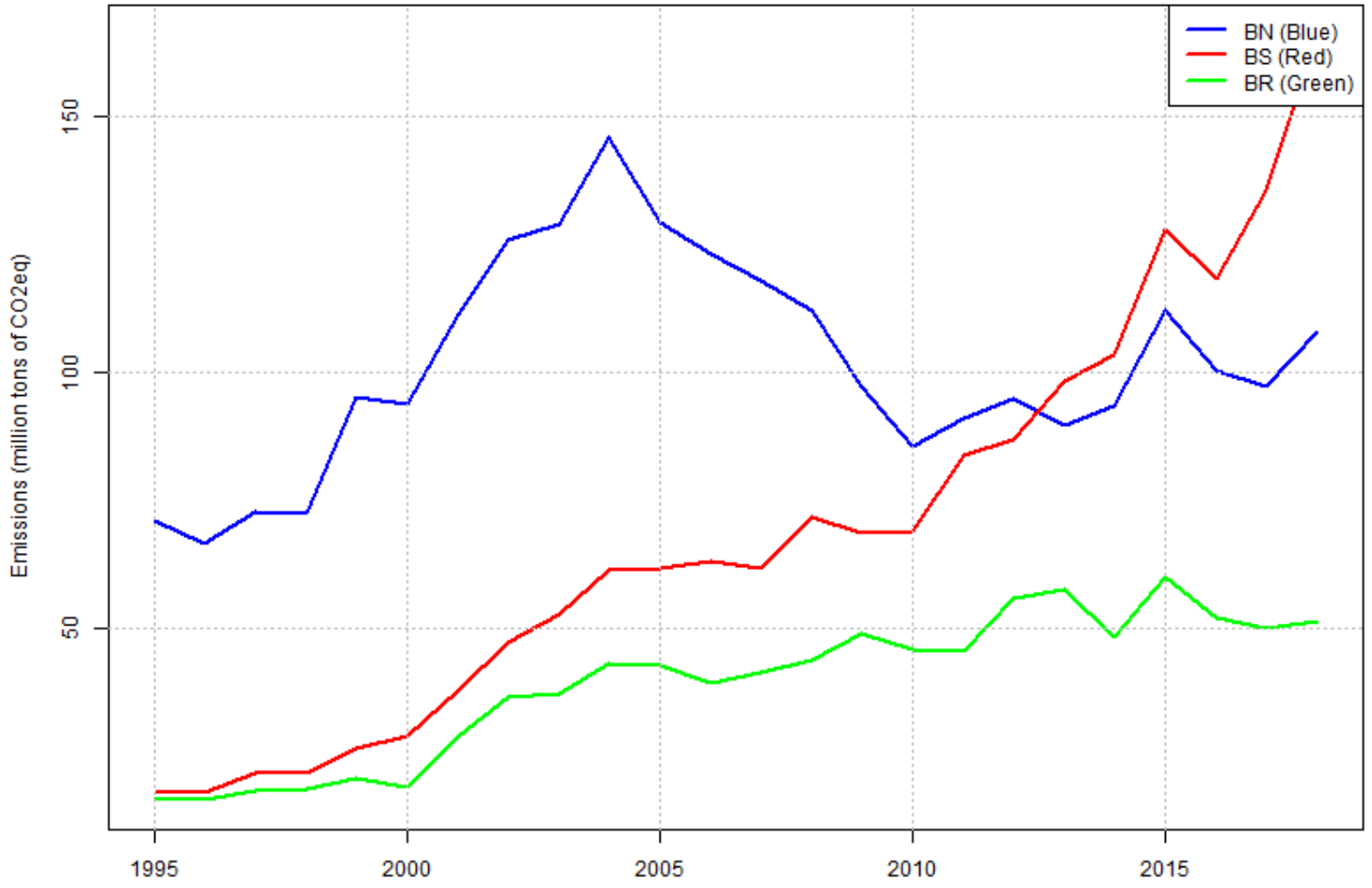
Net flow of carbon emissions

we can calculate the net flow of carbon emissions embedded in trade ($\boldsymbol{NT_{BS}}$) between Brazil and the Global South by the difference, such as:

- $\boldsymbol{NT_{BS} = CFX_{BS} - CFI_{BS}}$

Component	Description
Source	OECD ICIO (2021), covering 66 countries and RoW, 1995–2018
Sectors	45 sectors aggregated into 12 broad economic sectors
Regions	Brazil (B), Global South (S), Global North (N), Rest of World (R)
Country Groups	Global North: 33 developed countries Global South: 17 developing countries RoW: 16 residual economies
Emissions Data	From IEA-CO_2 and EDGAR databases Includes fossil fuels, land use, industrial processes
Units & Compatibility	CO_2eq in MtCO_2eq ISIC/IPCC sectoral alignment
Deflation Procedure	Double deflation with US deflators (STAN) Converted to constant 2015 USD
Deflation Limitations	Currency fluctuation bias Global price mismatch Additivity issues in accounts

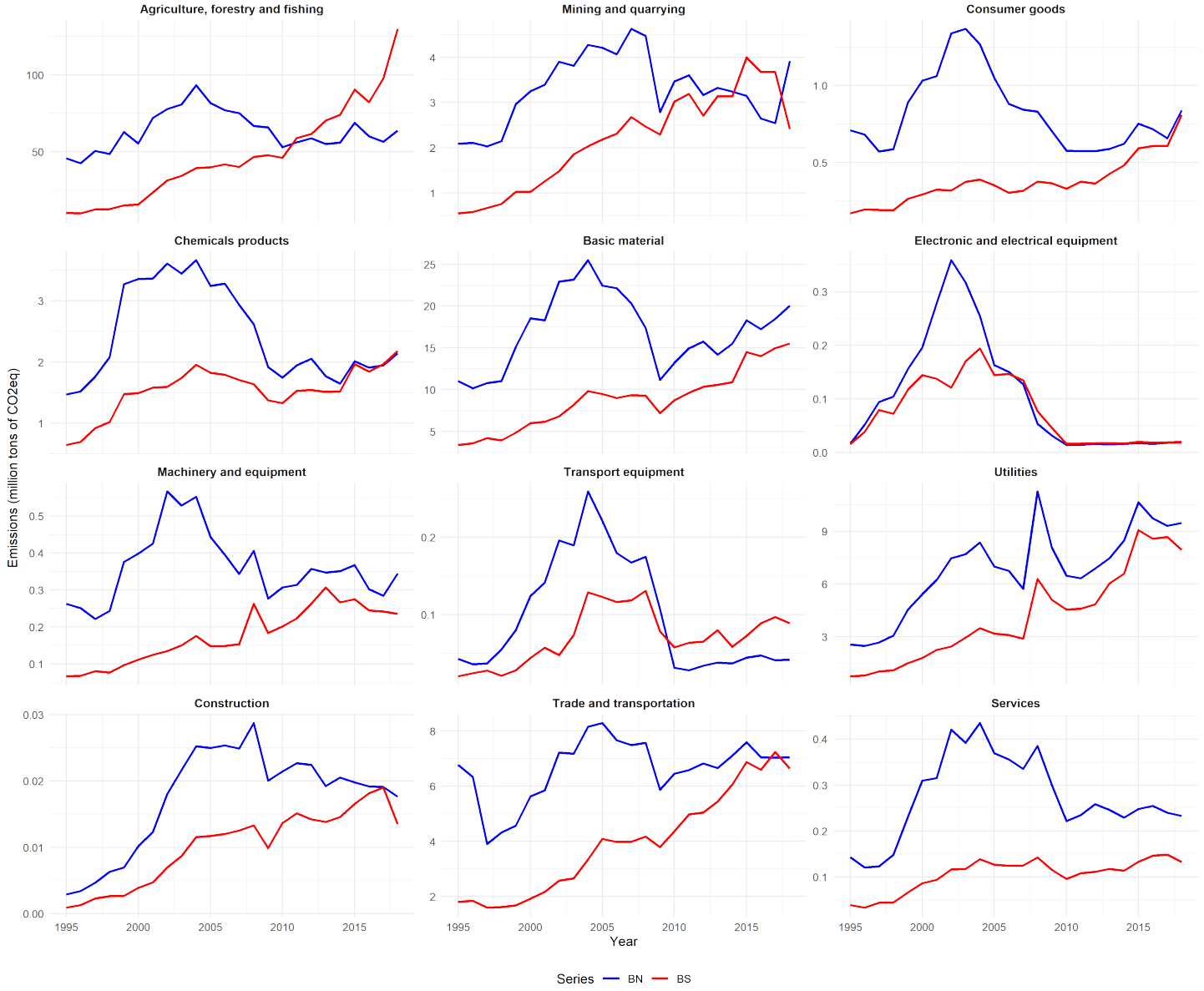
Carbon embedded in Brazilian exports to the Global North, South and rest of the world, 1995 to 2018



Carbon embedded in Brazilian exports to the Global North, South and rest of the world, 1995 to 2018

- The Global North led in absolute emissions volume until 2010.
- From 2010 onward, emissions to the Global South increased sharply, overtaking the North.
- This trend reflects Brazil's increasing specialization in primary exports (e.g., agriculture, mining).
- An abrupt drop in emissions to the Global North occurred between 2005–2010 (possibly due to methodological or structural changes).
- Emissions to the Rest of the World (RoW) followed a gradual and steady increase.

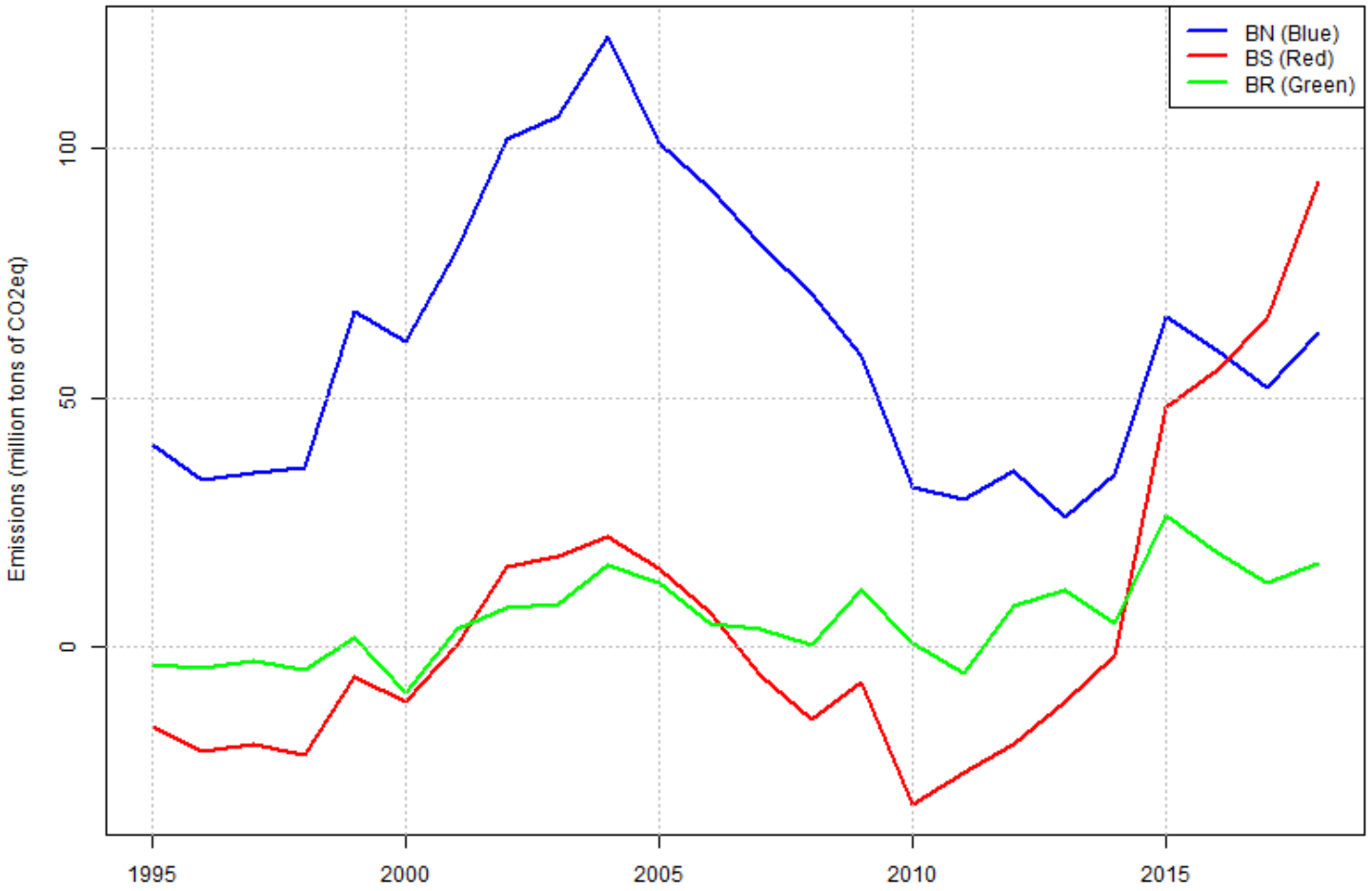
Carbon embedded in Brazilian Sectoral exports to the Global North and Global South, 1995 to 2018



Carbon embedded in Brazilian Sectoral exports to the Global North and Global South, 1995 to 2018

- Agriculture, Forestry and Fishing is the dominant source of CO_2 emissions to the Global South (~130 $MtCO_2eq$ in 2018).
- Basic Materials comes second (~15 $MtCO_2eq$), about 1/10 of agriculture emissions.
- Emissions to the Global South are catching up with those to the Global North over time.
- In most other sectors, emissions are higher to the Global North.
- The Transport sector is the exception, with more emissions to the South than the North.

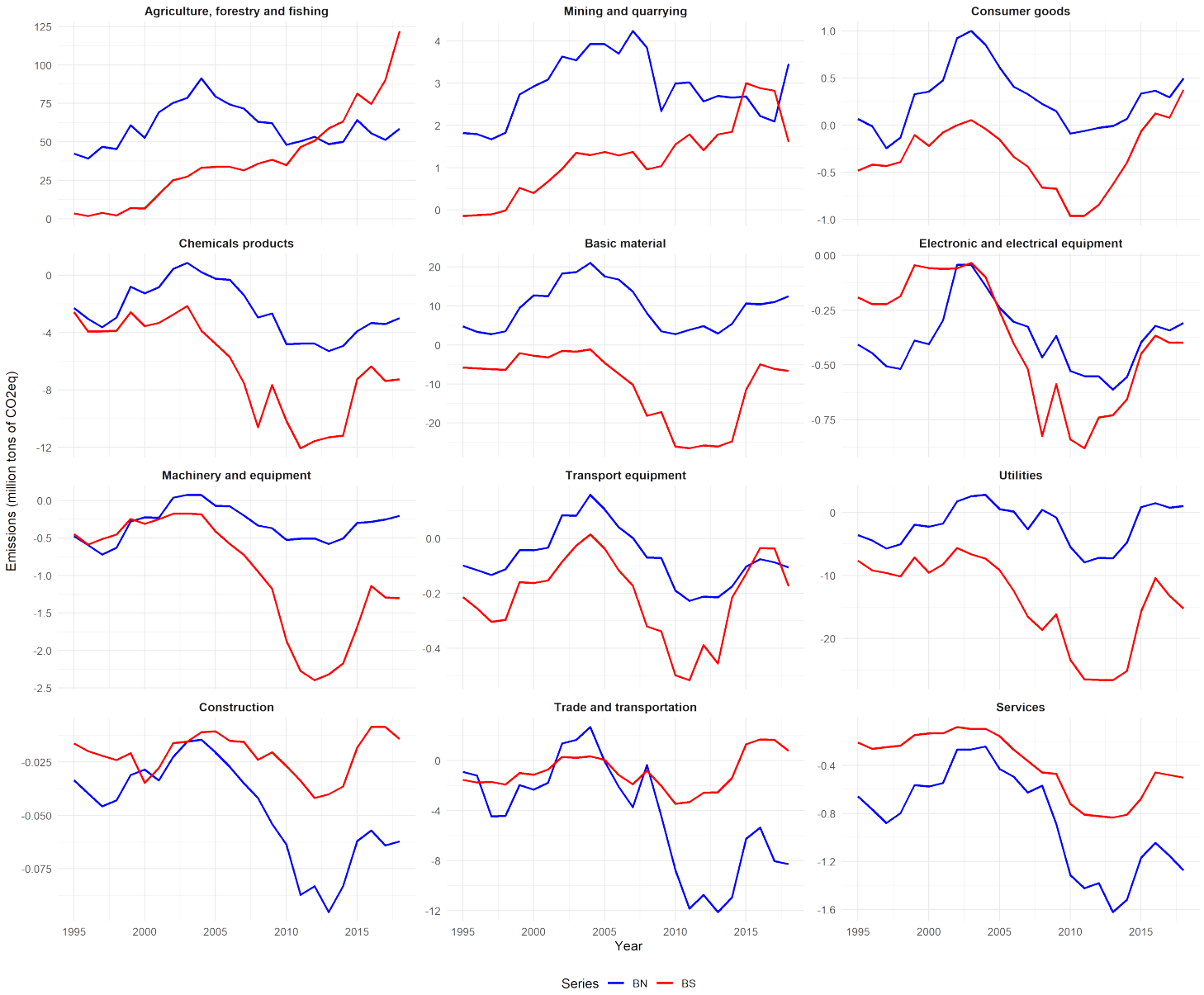
Net emission transfers of Brazilian trade to the Global North, South and rest of the world, 1995 to 2018



Net emission transfers of Brazilian trade

- Brazil is a net exporter of CO_2, especially in trade with the Global North.
- Emissions embedded in exports to the North account for ~⅓ of Brazil's positive net emissions.
- Distinct patterns across regions: Brazil consistently exports more carbon than it imports.

Sectoral net emission transfers of Brazilian trade to the Global North and Global South, 1995 to 2018



Sectoral Net Emission Transfers by Region

- Net exporter in resource-based sectors: Agriculture, Forestry, Fishing, and Mining.
- Net importer in technology-intensive sectors: Electronics, Machinery, and Chemicals.
- Asymmetries in sectors like Basic Materials and Consumer Goods: exporter to the North, importer from the South.
- **Brazil plays a dual role: supplier of carbon-intensive goods and importer of emissions in industrial and service inputs.**
  - Highlights Brazil's reliance on foreign industrial inputs and limited domestic production capacity in high-tech sectors.
- Persistent negative balances also observed in Utilities, Construction, Trade, and Services.

Final remarks

- Brazil's CO_2eq emissions embodied in trade are linked to exports to the Global North, but shares to the Global South have been rising.
- Still, Brazil consistently holds a net exporter position of emissions
- **Brazil plays a dual role in global trade: exporter of emissions (primary goods) and importer (industrial and tech inputs).**
- This pattern offshores industrial capacity while internalizing environmental costs, raising concerns about equity and sustainability.
- Attributing emissions is challenging: asymmetries in production, technology, and consumption between Brazil and its Global North partners complicate direct environmental accountability.

Thank you!

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Country groups

- **Global North**: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, South Korea, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, the United States, Cyprus, and Malta
- **Global South**: Chile, Colombia, Costa Rica, Hungary, Mexico, Poland, Turkey, Argentina, Bulgaria, China, Croatia, India, Indonesia, Romania, Russia, Saudi Arabia, and South Africa.
- **Rest of the World (RoW)**: Brunei, Cambodia, Hong Kong, Kazakhstan, Laos, Malaysia, Morocco, Myanmar, Peru, the Philippines, Singapore, Taiwan, Thailand, Tunisia, Vietnam, and the RoW itself.