Metal Footprint and Greenhouse Gas Emissions Embodied in South-South Trade: A Study of Brazil's Trade (2000–2019)

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Summary

Objective

This essay has a twofold objective: (i) to investigate the patterns of greenhouse gas (GHG) emissions associated with trade between Brazil, China, and the Rest of the World (ROW) from 2000 to 2019; and (ii) to analyze Brazil's material footprint in renewable energy value chains between 2015 and 2019. .

Why?

Since 2004, China's dynamism has impacted Brazil's export structure, leading to a significant increase in demand for commodities. In addition, there is an important discussion about the impact of the global energy transition in developing countries.

Research question and hypothesis

Research question

What are the effects of the bilateral trade patterns between Brazil and China on GHG emissions? And, given Brazil's role in global trade, how does the expansion of renewable energy value chains impact Brazil's material footprint?

Hypothesis

The central hypothesis is that the bilateral trade relationship between Brazil and China has evolved into a North-South trade, with higher direct and indirect effects on Brazil's total emissions. Also, the international position of Brazil's in world sustainable power system is in primary stages, in industries with relative lower value-added.

Trade patterns from a structuralist perspective

- Prebisch (1949) discusses disparities in development levels across the globe.
- The establishment of economically virtuous conditions in Global North countries contributed to the deindustrialization of many developing countries (or Global South).
- Persistent patterns remain in the integration of developing economies into international trade and value chains.
- The international trade regime also has significant environmental implications. The theory of ecologically unequal exchange (EUE) explores the socio-ecological impacts of trade patterns between countries and regions.

GHG emissions and metal ores embodied in trade

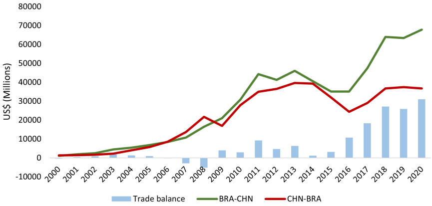
- Globalization sheds light on the emissions transference by international trade, which considers the emissions based on production and consumption (Grubb et al., 2022).
- In principle, a country can reduce its territorial emissions through regulation, new technologies, or improved energy efficiency. However, if consumption patterns do not change, the same country could simply allocate emissions to other countries through trade (Wood, 2020).
- In the literature, the process of allocating the environmental externalities by trade is studied by the pollution heaven hypothesis (Cole, Eliot, 2003; Frankel, 2009; Duan et al., 2021) and ecologically unequal exchange (Hornborg, 1998; Hornborg, 2023; Klink et al., 2024).

GHG emissions and metal ores embodied in trade

- In addition, related to the discussion of GHG emissions mitigation, the rapid transition to a global sustainable power system and clean technologies shed light on the intensive dependence on raw materials, metal ores, and other natural resources to build it (Wiedmann et al., 2015; UNEP, 2011; Hand et al., 2020).
- On the one hand, the formation of a sustainable power system is fundamental to reduce man-made greenhouse gas emissions and contribute to stopping global warming. On the other hand, the renewable energy infrastructure - such as the construction of solar panels, and wind and hydropower turbines - increased the global demand for heavy industries, such as mining and metal industries, and increased GHG emissions.
- The advancement of this discussion is driving research on environmentally extended multi-regional input-output (EE MRIO) models.

Patterns of trade and emissions: Brazil and China

Figure 1: **Exports, imports and trade balance of Brazil and China transactions (2000 – 2020)**



Source: Own elaboration based on WITS (2024).

- Scale effect: China is the most important trade partner with Brazil, while Brazil represents less than 2% of China's imports (WITS, 2024).
- Composition effect: Brazilian exports are concentrated in raw materials, accounting for 90.32% of total exports in 2021, while China accounted for 42.90% of capital goods in exports to Brazil.

Patterns of trade and emissions: Brazil and China

Figure 2: CO2e emissions of Brazil (1990-2020)

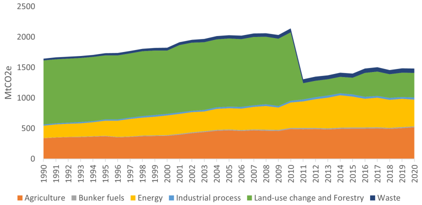
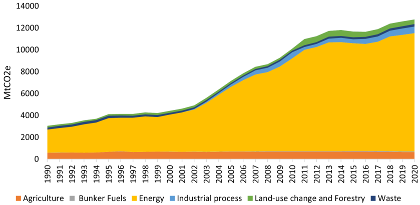


Figure 3: CO2e emissions of China (1990-2020)



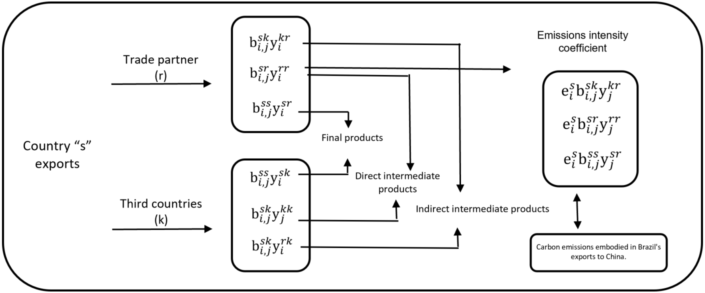
Source: Own elaboration based on Climate Watch (2024).

Methodology

Greenhouse gas emissions

Input-output analysis to estimate the direct and indirect effects of foreign demand in total production, in terms of GHG emissions.

Figure 4: Methodological fluxogram



Source: Own elaboration.

Methodology

Therefore, following the accounting method, we can measure the GEE emissions embodied in the relationship between Brazil, China, and RoW by the following indicators:

- *TC* - CO2e emissions generated by total consumption (domestic and foreign);
- $EC_{\text{Bra-ROW}}$ and $E_{\text{Chn-ROW}}$ - territorial CO2e emissions generate by foreign demand;
- $EC_{\text{Bra-Chn}}$ and $EC_{\text{Chn-Bra}}$ - CO2e total emissions embodied only in exports to the partners analysis;
- $NEC = EC_{\text{Bra-Chn}} - EC_{\text{Chn-Bra}}$ - Net Exports Carbon (NEC) represents the net CO2e emissions embodied in exports. If $NEC > 0$, it means that Brazil has a CO2e surplus embodied in exports to China; otherwise, if $NEC < 0$, Brazil has a CO2e emissions deficit in this trade.

Methodology

Metal footprint

The analysis is based on accounts in physical units (usually in terms of tons) of the inputs and outputs of groups of metal ores in the world's renewable power system.

- We calculate the metal footprint on renewable power chains by the following expression:

$$\hat{m}\,\mathrm{BY} = \begin{bmatrix} m^{s}_{\mathrm{nele}} & 0 & \cdots & 0 \\ 0 & m^{s}_{\mathrm{ele}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & m^{r}_{\mathrm{nele}} \end{bmatrix} \cdot \begin{bmatrix} b^{ss}_{\mathrm{nele,nele}} & b^{ss}_{\mathrm{nele,ele}} & b^{sr}_{\mathrm{nele,nele}} & b^{sr}_{\mathrm{nele,ele}} \\ b^{ss}_{\mathrm{ele,nele}} & b^{ss}_{\mathrm{ele,ele}} & b^{sr}_{\mathrm{ele,nele}} & b^{sr}_{\mathrm{ele,ele}} \\ b^{rs}_{\mathrm{nele,nele}} & b^{rs}_{\mathrm{nele,ele}} & b^{rr}_{\mathrm{nele,nele}} & b^{rr}_{\mathrm{nele,ele}} \\ b^{rs}_{\mathrm{ele,nele}} & b^{rs}_{\mathrm{ele,ele}} & b^{rr}_{\mathrm{ele,nele}} & b^{rr}_{\mathrm{ele,ele}} \end{bmatrix} \cdot \begin{bmatrix} 0 & 0 \\ y^{ss}_{\mathrm{ele}} & y^{sr}_{\mathrm{ele}} \\ 0 & 0 \\ y^{rs}_{\mathrm{ele}} & y^{rr}_{\mathrm{ele}} \end{bmatrix}$$

Methodology

Thus, according to Xu and Dietzenbacher (2014), we can write the metal footprint embodied in exports (MEE) as:

$$MEE^r = \sum_{s \neq r}^{N} (\hat{m}^r B^{rr} y^{rs}) + \sum_{s,k \neq r}^{N} \left(\hat{m}^r B^{rr} y^{rk} \right)$$

Analogue, the metal footprint embodied in imports (MEI) is given as:

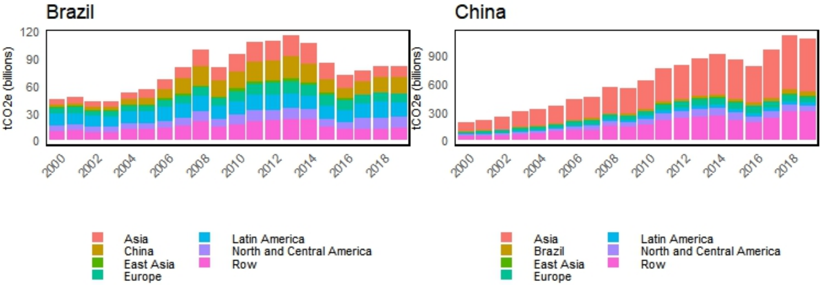
$$MEI^r = \sum_{s,k \neq r}^{N} \left(\hat{m}^k B^{ks} y^{sr} \right) + \sum_{s \neq r}^{N} (\hat{m}^s B^{sr} y^{rr})$$

Database

- The analysis employs EXIOBASE version 3 (Stadler et al., 2018).
- We consider the data of Brazil and China, and all the other countries were aggregated as Rest of the World (ROW), for the period 2000 to 2019.
- For the data on GEE emissions:
  - The main gases responsible for global warming: carbon dioxide (from combustion, agriculture, peat decomposition, biogenic and fossil waste), methane (from combustion, agriculture and waste) and nitrous oxide (from combustion and agriculture).
- For the data on metal ores:
  - We select the crucial metal ores in demand in renewable power sectors, considering the Hydroelectric power plants, Wind farms, and Solar power plants. The metals were aggregated into four categories: bulk metal ores (bauxite, copper, iron, lead, and zinc ores), precious metal ores (silver and platinum group metal ores), scarce metal ores (nickel and tin ores) and other non-ferrous metal ores, which are express in kilotons units (UNEP, 2011).

Analysis discussion

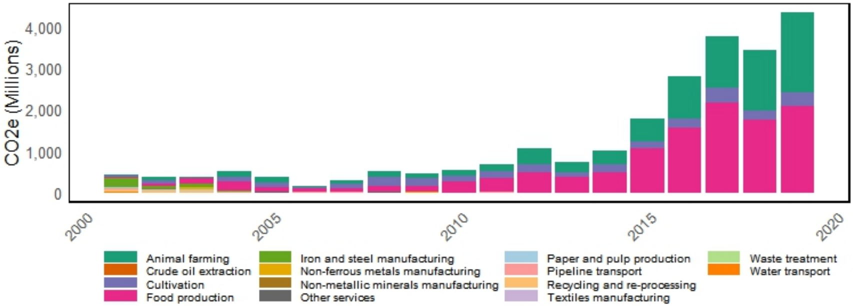
Figure 5: GHG emissions embodied in exports of Brazil and China, by economic partners



Source: Own elaboration based on EXIOBASE

Analysis discussion

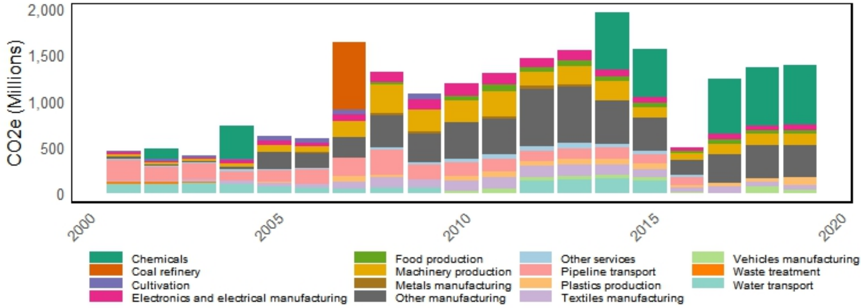
Figure 6: GHG emissions embodied in exports from Brazil to China (2000-2019)



Source: Own elaboration based on EXIOBASE

Analysis discussion

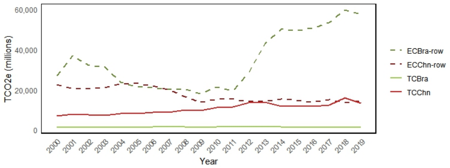
Figure 7: GHG emissions embodied in exports from China to Brazil (2000-2019)



Source: Own elaboration based on EXIOBASE.

Analysis discussion

Figure 8: **GHG emissions embodied in total consumption (TC) and international trade**

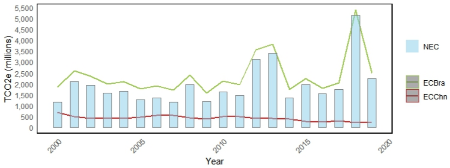


Source: Own elaboration based on EXIOBASE.

- We can see the positive trend of the total consumption GHG emissions of China, while decreased the territorial emissions for international trade (CHN_ROW).
- Brazil has maintained a stable position compared to China. However, it is noticing that the effects of territorial emissions for international trade have more impact than for total consumption.

Analysis discussion

Figure 9: **GHG emissions embodied in exports and NEC indicator: Brazil and China**

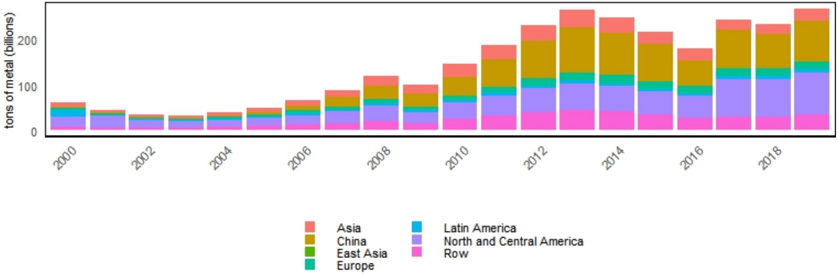


Source: Own elaboration based on EXIOBASE.

- The emissions level is associated with the exports volume, in a way that is possible to see a correspondence with Figure 1, and with the specialization pattern.
- Over the period, Brazil had a surplus (NEC > 0) in transactions with China, with an increasing tendency until the end of the period.
- Chinese industrial upgrading could be associated with the reduction of production-based emissions.

Analysis discussion

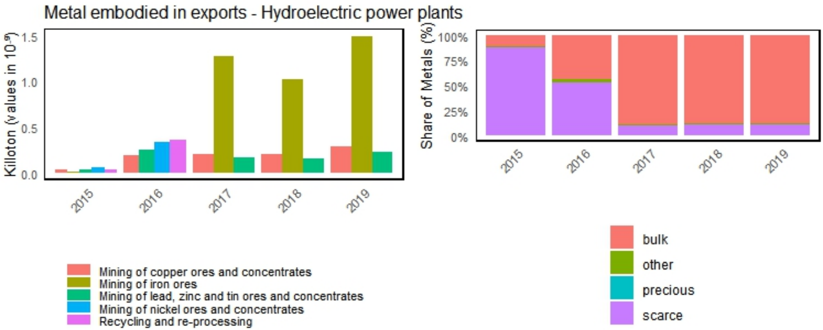
Figure 10: Metal ores embodied in exports of Brazil, by economic partners



Source: Own elaboration based on EXIOBASE

Analysis discussion

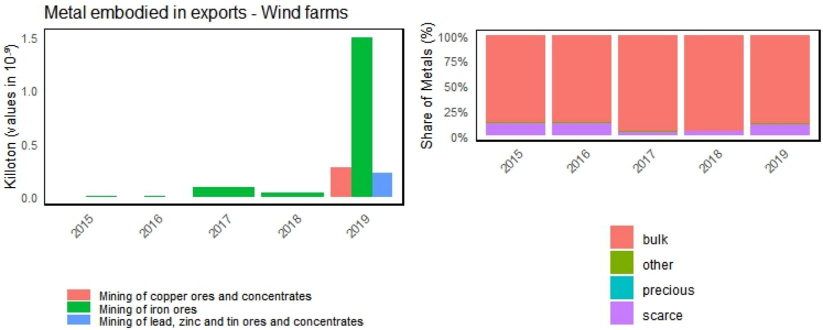
Figure 11: Metal embodied in exports - Hydroelectric power plants



Source: Own elaboration based on EXIOBASE

Analysis discussion

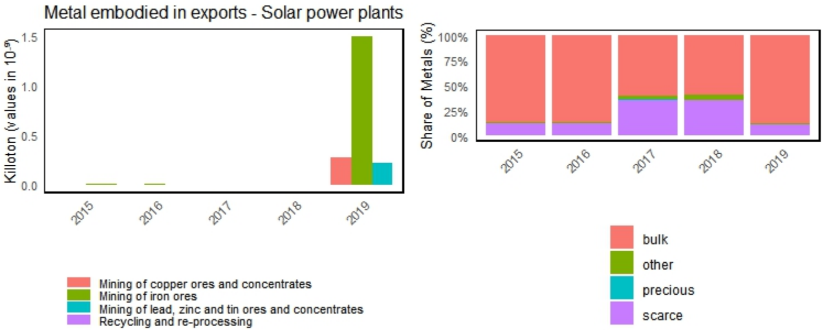
Figure 12: Metal embodied in exports - Wind farms



Source: Own elaboration based on EXIOBASE

Analysis discussion

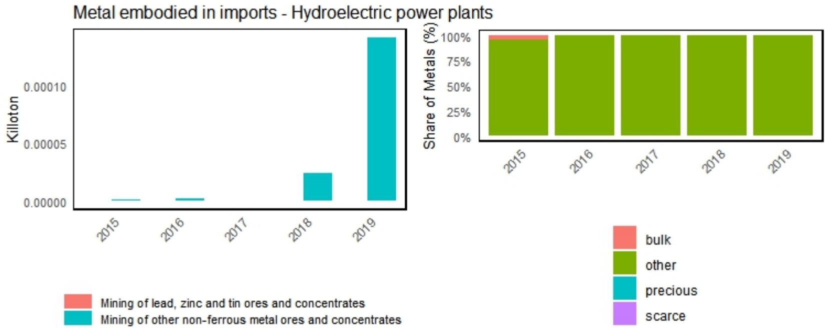
Figure 13: Metal embodied in exports - Solar power plants



Source: Own elaboration based on EXIOBASE

Analysis discussion

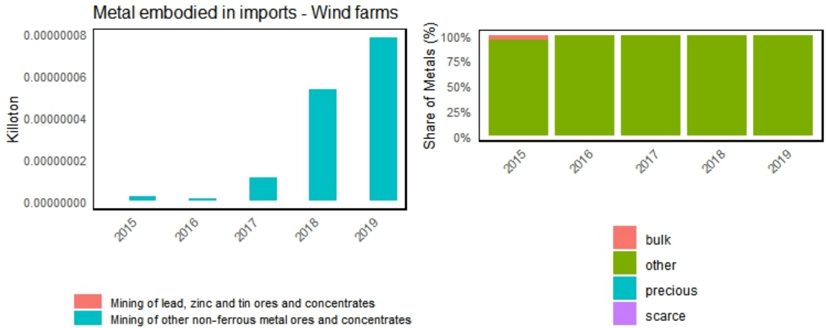
Figure 14: Metal embodied in imports - Hydroelectric power plants



Source: Own elaboration based on EXIOBASE

Analysis discussion

Figure 15: Metal embodied in imports - Wind farms



Source: Own elaboration based on EXIOBASE

Final considerations

1. This analysis allows for measuring the trade flows in terms of biophysical indicators, also identifying the sectors more intensive in GHG emissions and metal ores; mapping the transference of pollution on international trade and globalized production, and, finally, driving the better trade policy in the context of the climate crisis.
2. The results show that the bilateral trade between Brazil and China is suitable to the North-South pattern.
3. Net Emissions Carbon demonstrate that Brazil has had a surplus of GHG emissions on its transactions with China.
4. Based on this analysis and considering the strategic partnership between Brazil and China, we pointed out the principle of shared responsibility as a reference to design trade policies for these countries.

Final considerations

1. In the material footprint analysis, the results indicate that Brazil's role in renewable electricity value chains is in the mining stages, in the categories of bulk and scarce metal ores.
2. On the one hand, these sectors are positively affected by the low-carbon electricity system, which requires more material components than fossil-fuel electricity. On the other hand, the mining sectors generate the largest number of negative environmental externalities in Brazilian territory.
3. In this scenario, we pointed out that Brazil should find ways to improve material efficiency while seeking a better role in global renewable chains.

Thank you!

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