Palacký University Olomouc
University of Clermont Auvergne
University of Pavia

MASTER THESIS

Paula Daniela CASTELLS CARRION

Supervisor:

Miroslav Syrovátka, Palacký University Olomouc

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MASTER THESIS

Ecological Unequal Exchange. Evidence from Latin America

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Declaration:

I, Paula Daniela CASTELLS CARRION, declare that my thesis titled " Ecological Unequal Exchange. Evidence from Latin America " is the product of my independent work for the Erasmus Mundus Joint Master Program in Global Development Policy (GLODEP). I confirm that all the content in this thesis is my original work, and I have properly cited, referenced, and acknowledged all academic papers and secondary sources utilized in my research.

Paula Daniela Castells Carrion, May 2024

GLODEP

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Declaration of honour on the use of AI

During the writing of the submitted thesis, I used the following AI tools, Grammarly, Deepl and ChatGPT to check for spelling/grammatical mistakes, to check/improve my translations and to improve some of my formulations . After using this AI tool, I declare that I have reviewed and edited the text and I take full responsibility for the content of the submitted thesis.

Signature

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Paula Daniela CASTELLS CARRION

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Zásady pro vypracování

The theory of Ecologically Unequal Exchange (EUE) postulates that there are uneven and asymmetric transfers of resources from low-income peripheral countries to high-income core countries in the global trade system, perpetuating economic inequalities and hindering the development of peripheral nations (Dorninger et al., 2021; Hornborg 2019, 2014; Pérez Rincón, 2006; Samaniego et al., 2017). Additionally, EUE relations and the market interactions they entail, increase the vulnerability of peripheric countries to climate hazards and climate shocks (Warlenius et al., 2015). Empirical evidence provided by Hickel et al., 2021; Dorninger et al., 2021; and Infante-Amante & Krausmann, 2019; Althouse et al., 2023; among others, support these claims. This study aims to assess the extent of Latin America's (LA) involvement in Global Value Chains (GVCs) in contributing to EUE with core regions, specifically the European Union, from 2000 to 2015. This research involves analyzing the trade dynamics of biophysical resources concerning GVC involvement and value capture. Moreover, the research intends to examine normative guidelines shaping trade interactions and delve into the socioeconomic and environmental implications of EUE across various LA regions. The research will be used to provide evidence of EUE in Latin America to contribute insights to development discussions and inform policy-making frameworks on addressing inequality and asymmetries in market interactions.

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To the good vibes.

Abstract: This thesis explores Ecologically Unequal Exchange (EUE) in the trade relations between Brazil and the European Union (EU-29) from 2000 to 2022. While trade offers economic benefits, it also incurs significant environmental and social costs. This study integrates environmental flows into trade analysis, utilizing a semi-systematic literature review and Material Flow Accounting (MFA) to assess how Brazil-EU trade reflects EUE characteristics and how regulatory frameworks address these imbalances. Key questions investigate the evidence of EUE in Latin America, the specific traits of Brazil-EU trade, and the regulatory frameworks shaping these interactions. By contextualizing findings within Brazil's historical and policy landscape, the research provides a comprehensive understanding of EUE.The thesis contributes to EUE literature by offering nuanced insights into trade dynamics and methodological challenges. It underscores the need for responsible trade policies to address environmental injustice and promote sustainability in the context of global climate challenges**.** There is EUE in the flows between Brazil and the EU, in the period 2001-2022.

Key Words: Ecologically Unequal Exchange, power dynamics, material flows, Brazil.

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I. Introduction

Globalized trade enables us to buy phones, cars, or burgers. However, these benefits come with significant costs, particularly regarding environmental degradation and social inequality. Overall, the current trade regime is disadvantageous for countries whose economies depend on the extraction of natural resources; this implies intensive exploitation of these resources, a situation that predominantly affects nations in the Global South. Understanding global trade systems requires looking beyond mere monetary indicators to include environmental and resource-based flows (Rivera-Basques et al., 2021;Infante-Amate et al., 2022). Increasingly, academia highlights the concept of Ecologically

Unequal Exchange (EUE), which examines how ecological costs and benefits are unevenly distributed across different regions and countries (Althouse et al., 2020; Hornborg & Martinez-Alier, n.d.; Roberts & Parks, 2009)

Considering the multiplicity of different measures of EUE, it is crucial to compare and contrast the results. Another notable weakness in current EUE research is its tendency to analyze economies on a national level, overlooking sub-national disparities (Dorninger et al., 2021).Given Brazil's vast size and significant internal inequalities, it provides a crucial case study for understanding the nuances of EUE. Brazil's role is that of a major exporter of primary products (Porzecanski, 2015),thus amplifying the importance of studying its trade relations with the EU. This thesis aims to answer the following primary research question: How do material flows connected to trade between Brazil and the European Union (EU-27) from 2000 to 2022 reflect the characteristics of Ecological Unequal Exchange (EUE), and how do regulatory frameworks and market interactions address these characteristics?

To complement this inquiry, the thesis also addresses the following questions:

- (Q2) What are the critical material flow characteristics between the EU(27) and Brazil in 2000 to 2022?
- (Q3) Which regulatory frameworks have shaped the trade relations between Brazil and the EU (29) in 2000 to 2022?
- (RQ4), Is there empirical evidence of Ecologically Unequal Exchange (EUE) occurring in Latin America from 2000 to 2022? Is the Brazilian experience a reflection of a pattern in Latin America?

The research methodology combines a semi-systematic literature review, considering trade between Latin America and the EU, with a Material Flow Accounting (MFA) analysis of trade statistics between the EU and Brazil. Additionally, the findings will be contextualized within Brazil's historical and policy landscape, considering the MERCOSUR trade agreement and other relevant policies. This multifaceted approach aims to provide a comprehensive but nuanced understanding of EUE.

By answering these questions, the thesis aims to enhance the current EUE literature, particularly on Latin America and the EU. It will assess the coherence of various methodologies and offer insights into the limitations and conflicts inherent in different approaches. Additionally, the case study will only add depth and nuances to the current EUE literature.

From a societal perspective, this analysis will provide important insights to contribute to the development of responsible trade policies. Recognizing and addressing the complexities of trade practices is essential for fostering a fairer and more sustainable world in the face of climate change and environmental injustice.

The thesis is structured as follows: Chapter 2 reviews the relevant literature. Chapter 3 outlines the methodologies used and their limitations. Chapter 4 presents the results, which includes the case study on Brazil and semi-systematic literature review. Finally, Chapters 6 and 7 provide policy recommendations and conclusions.

II. Literature Review

In the first section, the literature review addresses the tradeoffs between economic growth and environmental degradation. Then is delves into Dependency Theories. It then explores the theory of Ecologically Unequal Exchange (EUE), including its main framework, different ways to approach it, as well as limitations of the theory. With this literature review, the purpose is to set the theoretical foundation for this research. Moreover, the aim is to examine critical work that would add into the research, the result analysis, and the discussion, bridging the theoretical

A. Economic Growth and the Environmental Degradation

In the field of development economics, a prevailing discourse posits that economic growth is the critical driver of welfare in countries and societies globally (*Barnjee and Duflo, 2004*, n.d.; Rodrik, 2014). Historically, approaches to economic growth have predominantly emphasized growth based on the exploitation of resources, which are then transformed into commodities and goods, contributing to the development of services (Alola, 2019a, 2019b; Bekun et al., 2019a; Akadiri et al., 2019). For a long time, the environmental aspect was disregarded in economic debates (Bekun et al., 2019). Environmental degradation, as well as social conflict and political unrest, have been accepted as the possible externalities of economic practices. However, the environment has come to the forefront of contemporary discussions, strategies, and policies promoted by and for developing and developed countries worldwide (Emir & Bekun, 2018; Sarkodie, 2018; Shahbaz & Sinha, 2019). A clear example is the 2030 Agenda and the Sustainable Development Goals, a framework promoted by the United Nations to guide countries, civil society, and the private sector towards more sustainable policies.

According to Conservation Energy Future [CEF], 2016, environmental degradation is the term used to describe how the environment deteriorates due to pollution, ecosystem devastation, species extinction, and the depletion of resources like air, water, and soil. The High-level Panel on Threats, Challenges, and Change of the United Nations has named it one of the ten significant threats. Numerous factors contribute to environmental degradation, such as loss of habitat, depletion of resources, extinction of species, and contamination of the air, water, and soil (CEF, 2016).

Economic growth can negatively impact the environment through pollution, overexploitation of natural resources, degradation, loss of wildlife habitats, and climate change (Bansard & Schröder, 2021; Phimphanthavong, 2013). These changes are often driven by an expanding human population and escalating economic activities that rely on resource-intensive technologies. The continuous economic growth nations seek often results in environmental compromises, illustrating a complex trade-off between development and ecological sustainability. Environmental degradation, both in quantity and quality, is a significant hallmark of industrialization and development, which are critical drivers of economic growth (Aye & Edoj, 2017). The relationship between economic growth and environmental degradation is further complicated by the internal characteristics of each country and its position in the world system structures. In this line, countries in the Global South, rich in natural resources, have historically been providers of raw materials and natural resources. Their economic sustenance depends on exploiting natural resources and, therefore, environmental degradation.

B. Dependency Theory and World System Theory

Dependency Theory provides a critical framework to examine global inequalities, power dynamics, and development. Originating in the 1950s within the reflections of the UN Economic Commission for Latin America and the Caribbean (ECLAC) on the economic stagnation and underdevelopment of Latin America (Bielschowsky, 1998), Raúl Prebisch (1962) and André Gunder Frank (1967) argued that the “underdevelopment” of Latin America and the Global South (GS) was not a stage toward modernization but a condition perpetuated by global economic and political structures that primarily benefit the Global North (Prebisch, 1949; Frank, 1967).

Prebisch posited that global economic structures divide countries into centers and peripheries. Peripheral countries (Global South) are structurally disadvantaged due to their economic dependency on core countries (Global North), which control and benefit from global trade and capital flows (Prebisch, 1949). Dependency Theory suggests that peripheral countries export raw materials and import manufactured goods from core countries, leading to persistent poverty and underdevelopment in the periphery (Dos Santos, 1970).

Building on Dependency Theory, Immanuel Wallerstein developed World-System Theory (WST) in the 1970s, proposing a single economic system characterized by a division of labor and a hierarchical structure comprising a core, a semi-periphery, and a periphery (Wallerstein, 1974). Core countries dominate high-technology industries, while peripheral countries are relegated to low-profit, labor-intensive activities. Semi-peripheral countries occupy an intermediate position, stabilizing the system by engaging in core and peripheral activities (Wallerstein, 1974). These structures ensure a continuous flow of economic surplus from the peripheries to the core, perpetuating global inequalities and enhancing the wealth and power of the Global North (Chase-Dunn & Grimes, 1995; Frank, 1978).

Both frameworks help understand how international trade and investment perpetuate inequalities and hinder development in peripheral countries by highlighting the structural imbalances and power dynamics that shape global economic relations (Dos Santos, 1970; Amin, 1976). Peripheral countries focus on low value-added and extractive sectors, which core countries use to increase their technological infrastructure and economic growth (Hornborg, 2018; Dorninger et al., 2021). However, these theories overlook environmental analysis. They fail to acknowledge how environmental degradation, such as pollution and deforestation, limits development prospects by depleting natural resources (Hornborg, 2018; Dorninger et al., 2021). Incorporating environmental sustainability into these frameworks would provide a more comprehensive understanding of global inequalities and support policies that balance economic and environmental justice (Martinez-Alier, 2002; Muradian & Martinez-Alier, 2001).

C. Ecological Unequal Exchange Theory: An Overview

The theory of Ecologically Unequal Exchange (EUE) postulates that there are uneven and asymmetric transfers of resources from low-income peripheral countries to high-income core countries in the global trade system, perpetuating economic inequalities and hindering the development of peripheral nations (Dorninger et al., 2021; Hornborg 2019, 2014; Pérez Rincón, 2006; Samaniego et al., 2017). Additionally, EUE relations and their market interactions increase the vulnerability of peripheric countries (Global South) to climate hazards and climate shocks (Warlenius et al., 2015). Empirical evidence provided by Hickel et al., 2021 Dorninger et al., 2021 and Infante-Amante & Krausmann, 2019 Althouse et al., 2023 among others, support these claims.

Moreover, the EUE highlights the hidden costs of trade, trying to shed light on the social and environmental impacts that are embedded in international exchange, which are more costly for peripheric countries, where regulations for resource extraction and reduction of environmental degradation continue to be weak, in comparison to high-income core-countries (Roberts & Parks, 2009; Rice, 2007; Guljum & Eisenmenger, 2004). This asymmetrical transfer would maintain economic inequalities in the world by benefiting the Global North countries to the detriment of the peripheries (Althouse et al., 2023), hindering low-income countries' chances to increase their capacities to accumulate the resources and technologies that would allow them to catch up with the GN countries. At the same time, EUE relations and the market interactions they entail increase the vulnerability of peripheric countries to climate hazards and climate shocks (Warlenius et al., 2015).

Even though the EUE was initially just theoretically documented and analyzed as part of the World System Theory and the Core-Periphery theory, several efforts have been conducted in the last 20 years to provide empirical evidence for this theory. Among the most recent works are Hickel et al., 2021; Dorninger et al., 2021; and Infante-Amante & Krausmann, 2019. These researches, among others, provide evidence on how EUE relations benefit core countries at the expense of peripheric countries, which have to deal with the burdens of environmental degradation and social damages. This empirical work has provided valuable insight into the mechanism and implications of the EUE. However, as Dorninger and Hornborg (2015) explain, tools used to quantify the EUE, such as the environmentally-extended multi-regional input-output (EEMRIO), are based on a series of assumptions requiring further analysis and understanding.

Proponents of liberal international trade argue that trade relations benefit all engaged nations; however, they often overlook the raw material aspects of trade flows (Dorninger et al., 2022). This is where EUE comes into play by stressing material relations, highlighting an asymmetry in the net transfer of resources from peripheries to cores within the global economic system (Dorninger et al., 2022). This net transfer of resources, including capital and technological infrastructure, is fundamental to capital accumulation and economic growth (Dorninger et al., 2022).

In this line, power relations are a critical EUE dimension defining the interaction between core and peripheral countries. Core countries use political and economic power to enforce their will on trade agreements and investment policies that serve their interests at the expense of peripheral countries (Jorgenson, 2016; Givens et al., 2019). International institutions like the IMF and World Bank reinforce these dynamics by promoting neoliberal policies prioritizing free trade and investment over local development needs, exacerbating environmental degradation and social inequalities (Rice, 2007).

The gap between technology and the global production network widens the power dynamics. Core countries acquire technologies to support innovation, while the periphery remains trapped in low-value-added production processes, facing more significant environmental and societal costs (Hornborg, 2014). Core countries can more easily transfer the most socially and environmentally destructive aspects of production to the periphery (Frey, 2018; Hornborg, 2001, 2006; Rice, 2007). This asymmetry maintains global inequalities and hinders peripheral countries' development (Althouse et al., 2023).

In general, the EUE theory elaborates on how global trade is responsible for perpetuating environmental and social inequalities. This model contrasts with mainstream economic theories that support free trade to enhance global welfare and seeks a more complex approach to understanding international trade's material and ecological impacts. Addressing these challenges requires rethinking trade policies and fostering sustainable development practices toward the just distribution of resources and environmental protection (Dorninger et al., 2020; Hornborg, 2009).

The EUE framework is indispensable for understanding the intersections of power, trade, and international dynamics. It calls for policies addressing economic and ecological trade dimensions to achieve global equity and sustainability (Hornborg, 2019; Infante-Amate & Krausmann, 2019).

Policymaking should be inclusive and fair, guided by this understanding of power relations and structural imbalances in the global economy, promoting environmental sustainability and social equity (Roberts & Parks, 2009).

D. Measuring EUE

Various methodologies have been developed to quantify Ecological Unequal Exchange (EUE), each possessing specific strengths and limitations. Material Flow Analysis (MFA) quantifies the physical products and waste that cross country borders, tallying the quantity and category of materials exported and imported. This technique identifies the mismatch between resource extraction and consumption. For instance, Roberts and Parks (2009) used MFA to map material flows, revealing that developed countries benefit from developing countries' ecological resources, leading to environmental degradation in the latter.

Ecological Footprint Analysis describes the environmental impact of consumption patterns by comparing the ecological footprint and biocapacity to gauge sustainability. It highlights the ecological deficits in core countries, offset by resource imports from peripheral countries. Givens and Jorgenson (2013) used this method to demonstrate the environmental burdens embodied in trade, emphasizing the ecological costs borne by developing countries.

Environmentally Extended Multi-Regional Input-Output (EEMRIO) models combine economic and environmental information to analyze the environmental impacts embedded in trade. They trace the entire environmental burden from extraction to final consumption. Dorninger et al. (2021) used EEMRIO models to track the environmental burden shifting from core to peripheral countries, illustrating the hidden ecological costs of trade. Furthermore, Carbon Footprint Analysis accounts for the carbon emissions from producing and transporting traded goods. This method provides insights into the carbon-intensive nature of raw material exports from peripheral countries to core nations. Peters et al. (2011) applied Carbon Footprint Analysis to global trade flows, revealing significant disparities in carbon emissions.

Empirical studies using these methodologies consistently show that peripheral countries export low-value raw materials while importing high-value manufactured goods, resulting in unfavorable trade balances and significant environmental impacts (Hickel et al., 2021; Dorninger et al., 2021).

However, these methodologies face limitations due to assumptions like the equivalence of different materials based on weight, which may not accurately reflect their environmental or economic value (Dorninger & Hornborg, 2015).

Key indicators and metrics include the Net Transfer of Resources, which considers the balance between the value of raw materials exported by peripheral countries and the high-value goods imported from core countries, highlighting the economic disadvantage peripheries face (Dorninger et al., 2022). Ecological Footprint and Biocapacity measure the ecological impact of resource consumption and the capacity to regenerate these resources. Core countries often have more ecological footprints than their biocapacity, indicating an ecological deficit compensated by resource imports from peripheral countries (Hornborg, 2014).

Infante-Amate and Krausmann (2019) utilized physical trade balances and Multi-Regional Input-Output (MRIO) models to analyze ecological terms of trade, providing empirical evidence of the ecological costs associated with trade. Their research underscores the need for comprehensive tools to assess EUE. Dorninger and Hornborg (2015) advocate for developing comprehensive methodologies to assess the full spectrum of EUE impacts. They emphasize the importance of considering the entire value chain in trade analyses to capture the full extent of ecological impacts, arguing for more sustainable trade practices.

Muñoz et al. (2011) provided empirical data on the ecological impacts of global commodity chains in Latin America, showing how the extraction of natural resources for export leads to significant environmental degradation. Their study illustrates the hidden ecological costs associated with EUE and calls for policies addressing these impacts to achieve sustainability.

The measurement of EUE through methodologies like MFA, Ecological Footprint Analysis, and EEMRIO provides a comprehensive understanding of global trade material and environmental disparities. By highlighting the asymmetric resource flows and their ecological impacts, EUE underscores the need for more equitable and sustainable trade practices that address economic and environmental dimensions. This approach challenges mainstream economic theories and advocates for policies promoting global equity and sustainability (Roberts & Parks, 2009; Hornborg, 2019)

E. EUE: Critiques and limitations

The EUE theory has shed critical light on global environmental inequalities, notably in how the flows of resources from the Global North to the Global South imply environmental degradation and economic disparities. Despite its relevance to analyze the environmental aspects of trade and economic activities, there are several limitations to this theory. One of the main critiques is that the theory is limited in including an institutional perspective that analyzes how governance indicators, local practices and regulatory frameworks might add or affect the EUE outcomes (Hornborg, 2009).

Another concern is connected to the deterministic view in which countries might be considered peripheric countries and which countries might be considered core countries. As Wallerstein explains (1979), there is certain degree of fluctuation in the international system. Moreover, there are players adding layers of complexity to international trade through the Global Value Chains (Wang et al, 2020). This has been reflected in the trade dynamics of China, for example. China is now playing a crucial role in the consumption and acquisitions of raw material, commodities, and goods, from all around the globe, and its practices are criticized for natural resources depletion. However, there are several studies claiming that China is playing a role as a semi-peripheric country, using extracted resources from peripheries, producing manufactured goods, and then redistributing these goods into the cores (Wang et al, 2020; Kostoska et al., 2020). The ecological inequalities are, however, absorbed by China, and by the countries supplying to it.

Another is the methodology used by the EUE research. Most of these approaches usually rely on aggregate data, concealing the disparities within the countries and the actions of sub-national stakeholders. Using national-level data masks critical ecological and economic interactions that are most likely to occur at regional or local levels within the countries. This aggregation can, however, lead to paradoxical conclusions regarding the reach and scale of unequal exchanges and the ability to streamline debates on 'just distribution' (Roberts & Parks, 2009). Such a tendency becomes evident in a critical understanding of most EUE analyses, which have been termed static and, hence, failed to be put into context with the evolving nature of trade and environmental policies at the global level. For example, shifting tendencies in global trade agreements, changes in environmental regulation, and changes in technology will alter the pattern and impact of resource transfer over time. There is, therefore, a need to demarcate the dynamics of issues and provide a projection that informs the unfolding view of ecologically unequal exchange (Hornborg & Martinez-Alier, 2016).

F. Comparative advantages and free trade

The principle of free trade, which is based on the comparative advantage model, asserts that the distinct advantages of any nation can be utilized to maximize worldwide effectiveness and economic expansion (World Bank, 2002). However, this idea frequently needs to be revised for nations in the Global South. Due to their structural adjustment initiatives from organizations such as the IMF, poverty, and debt, many of these countries specialize in the same primary sectors (Raffer & Singer, 2001; Gilgum & Eisenberg, 2004). Structural adjustment policies is a conflicting topic, and policies connected to them are still at the center of debates. On the one hand, there are those who argue that they have not effectively addressed the region's development problems (Baer, 1972; FitzGerald, 2000). On the other hand, there are those who claim that these policies initiated the transition towards productive structures beyond the commodity-export model, generating opportunities for the development of industry in the region (Crespi, 1997).

Furthermore, for these nations to industrialize, they frequently need to purchase technology from the North, which is paid for by debt or resource exports. Due to the South's inexpensive energy and resources, this dynamic helps the industrialized North (Dorninger et al., 2020). Proponents of trade liberalization contend that by raising tax revenues for environmental protection, economic growth via free trade can improve environmental sustainability (Bhagwati, 1993; Dasgupta et al., 1995). This viewpoint, however, ignores the enormous ecological costs that coming generations will have to pay, emphasizing the necessity of sustainable environmental management (Clayton et al., 2016). Moreover, conventional economics accepts natural resource depletion as a market consequence, which frequently ignores the material aspect of trade (Dorninger et al., 2020).

The idea that free trade always promotes development and sustainability is questioned because, although specialization and free trade may theoretically strengthen global economies, their real-world effects on the Global South include economic instability and environmental degradation (Gilgum & Eisenberg, 2004). Because many southern countries are forced into identical industries, leading to market oversaturation and falling commodity prices, the notion of unique comparative advantages needs to be revised. Due to the ensuing economic pressure, these nations are forced into debt and dependency cycles, exacerbating inequality and underdevelopment (Raffer & Singer, 2001). Therefore, free trade frequently makes peripheral countries' problems worse rather than better.

III. Methodology

Ecologically Unequal Exchange (EUE) in Latin America is facilitated by international institutions advocating for a commodity specialization and export model. These institutions support the liberal economic model, which emphasizes specialization based on comparative advantages, as a pathway for growth and development in the region. Evidence indicates that EUE is present in Latin America. To understand this phenomenon better, it's crucial to examine specific trade relationships. For instance, Brazil, despite being an upper-middle-income country (UMIC), heavily relies on commodity exports. This case is particularly significant because Brazil is the largest economy in Latin America. Analyzing Brazil's main commercial interactions can reveal the extent of EUE in its trade practices. Additionally, it is essential to consider how regulatory frameworks enable EUE. The European Union (EU) is a leading advocate for a just transition, combating climate change, and environmental protection. However, a contradiction emerges between the sustainable practices the EU promotes domestically and those it encourages in its external trade relationships. This inconsistency is evident in the EU's trade agreements with other countries.

This research implements a mixed approach, relying on quantitative and qualitative data to address the following research questions:

Main Research Question (Q1): How do material flows connected to trade between Brazil and the European Union (EU-27)[1] from 2000 to 2022 reflect the characteristics of Ecological Unequal Exchange (EUE), and how do regulatory frameworks and market interactions address these characteristics?

Supporting Research Questions:

[1] EU 27 include: EU 27 listing: Austria, Germany, Belgium, Bulgaria, Czechia, Cyprus, Croatia, Denmark, Slovakia, Slovenia, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Portugal, Romania, and Sweden

(Q2) What are the key characteristics of material flows between the EU(27) and Brazil in 2000-2022?

(Q3) Which regulatory frameworks have shaped the trade relation relations between Brazil and the EU (29) in the period 2000-2022?

(RQ4), Is there empirical evidence of Ecologically Unequal Exchange (EUE) occurring in Latin America from 2000 to 2022? Is the Brazilian experience a reflection of a pattern in Latin America?

The complementary research questions respond to different aspects of the main research question. Thus, a specific research method is proposed to address each of them

A. Step 1: Brazil and Material Flow Accounting

Material Flow Accounting (MFA) is a methodological tool that accounts for the material flows generated in a territory through the socio-economic activities carried out in that territory (Fischer-Kowalski et al., 2011; Sygulla et al., 2014). By focusing on flows, MFA accounts for the biophysical dimension (i.e., on the physical quantity) of resources that are extracted from a territory, thus allowing to study the environmental pressures that are generated through extraction activities linked to the territory's internal consumption and trade flows (EUROSTAT, 2018; Fischer-Kowalski et al., 2011; Infante-Amate et al., 2022). In addition, MFA allows monitoring productive profiles, commercial specialization and levels of national economies in biophysical terms (Haberl et al., 2019; Infante Amante et al., 2022; Samaniego et al., 2017). Furthermore, given the correspondence of material flows with monetary flows (Schaffartzik et al., 2015), the biophysical implications of monetary flows can be analyzed.

Given these characteristics, MFA is a tool of great value in Ecologically Unequal Exchange studies, which is why it has been widely used in empirical EUE studies (Giljum, 2004; Hornborg, 2009; Jorgenson, 2016; Muñoz et al., 2009; Samaniego et al., 2017a). Along these lines, and following Infante Amante et al., (2020); Alonso Fernádez & Regueiro-Ferreira (2022); and Samaniego et al., (2016), Material Flow Accounting is used to address the main research question of this study Q1): How do trade relations between Brazil and the European Union (EU-27) from 2000 to 2022 reflect the characteristics of Unequal Ecological Exchange (EUE), and how do regulatory frameworks and market interactions address these characteristics? Which is supported by Q3 What are the key characteristics of material flows between the EU-27 and Brazil from 2000 to 2022, and how have variations in these flows responded to policy changes?

Data to analyze EUE between Brazil and the EUE in the period 2001-2022

To analyze the biophysical transaction between Brazil and the EU29 and to study whether these interactions reflect EUE characteristics, the data available in the UN Comtrade Database is used. This database provides data on trade interactions between different countries, being able to filter these interactions by reporter country, in this case Brazil, and partner country, in this case EU29. It should be noted that there is no aggregated data covering the trade dynamics of Brazil with all EU countries, so it was necessary to extract data from each of the 29 EU29 countries.

The COMTRADE database uses the Harmonized System (HS) an internationally standardized system developed by the World Customs Organization (WCO), which provides names and numbers for classifying traded commodities (WCO; n.d). The HS system has different levels of commodity aggregation, ranging from broader categories such as "Fruits and vegetables" (HS1 level categorization) to specific categories such as "fruits, edibles, pineapples fresh or dried" (HS6 level categorization, 6 digits). In order to estimate the indicators described above, it is necessary to have volumetric information on import and export flows from Brazil to the EU. This information is available starting at HS4 level (4 digits), for a total of 1,241 commodities.

For analysis purposes and following Eurostat 2028, as well as Infante Amante et al., 2020, Rivera-Basques et al., 2021; Dorninger & Hornborg (2015), these commodities were classified into 5 categories and the net weight in millions of tons and the corresponding trade value (in millions of USD) were estimated for each category and year. These categories are used to understand with more depth different types of resources, their use, and the environmental impacts associated with their lifecycle.

Table 1:Material Flow Caterorization

Category	**Description**

Biomass and biomass products	It consists of substances of biological origin, excluding those transformed to fossil fuels (Eurostat, 2018). This includes all organic materials coming from plants and animals, including raw materials from agriculture and forestry activities.
Metal ores and concentrates, raw and processed	Materials (usually rocks) extracted from the earth that contain metals in a quantity sufficient to justify mining (Eurostat, 2018), bot extracted and processed. Such as cooper, silver and iron.
Non-metallic mineral, raw and processed	Minerals that do not include metals, such as sand gravel, limestone, and clay.
Fossil energy materials/carriers, raw and processed	It refers to fossil energy materials/carriers as energy resources obtained from fossilized organic remains (Eurostat, 2018).

Manufacture goods, on the other hand, are all those goods processed or manufactured.

However, in order to understand and gain insight on which commodities represent a greater biophysical quantity in trade between the US and Brazil, they were reclassified following the HS2 categories. In this way, we seek to gain nuance in the information and maintain a higher level of disaggregation. This is in studied in section IV, under the analysis of regulatory frameworks.

Indicators to analyze EUE between Brazil and the EUE in the period 2001-2022

Material Flow Accounting allows to quantify and estimate several indicators which provide insight of environmental pressure in a territory because of resource extraction and trade activities. Table xxx displays a description of each indicator, as well as what are they proxies for.

Table 2: MFA indicators and descriptions

Indicator	**Description**	**Proxy for:**

Domestic Extraction (DE)	DE is the total amount of material resources extracted within a specific political-territorial unit, such as a region or a country.	DE serves as a proxy for pressure on the domestic environment (Steinmann et al., 2017)
Physical Trade Balance (PTB)	Measures the difference between biophysical quantity of imported and exported materials. (Imports minus exports)	Whereas a positive PTB suggests an economy is a net resource demander, a negative one would suggest that an economy is a net resource supplier (Infante Amante et al., 2020; Alonso Fernádez & Regueiro-Ferreira, 2022; OECD, 2008). Indicating the outsourcing of environmental impacts to third countries (Giljum & Eisenmenger, 2004).

Additional to this indicators, and following Infante Amante et al., 2020, the ration (RI) between the monetary values per unit of total physical imports and physical export is estimated. “If RI is greater than one, then the price per ton of imports is higher than the price per ton of exports” (Infante Amante et al., 2020, p2).

$$RI_i = \frac{m_i}{x_i}$$

RI will show the monetary value per unit of the total physical imports divided by the monetary value per unit of total physical exports. The interpretation of this indicator is connected to monetary trade balance, indicating that maintaining a trade balance equilibrium requires for a higher quantity of biophysical materials to be sold. This is connected to resource depletion (Alonso Fernádez & Regueiro-Ferreira, 2022; Muñoz et al., 2011; Infante Amante et al., 2020).

Additional data

The UN Environmental Program provides aggregate data on the aforementioned indicators covering DE, PTB, DMI and DMC covering biophysical quantities for all Brazilian trade relations. This data is available by year, allowing you to see overall variations by year. However, this data does not allow us to see specific dynamics between regions, so it does not provide input to answer the research question. However, this data is used to show overall trade dynamics of Brazil, as well as indicators for Latin America, adding to the discussion in section.

B. Step 2: The regulatory frameworks

To address **(***Q3) Which regulatory frameworks shape the trade relations between Brazil and the EU (29) in the period 2000-2022? How are these frameworks addressing EUE?,* a qualitative normative analysis is conducted, based on the policy coherence framework.

Policy coherence is a policy framework that helps identify and address potential conflicts or inconsistencies between different sectors and policies, while providing crucial insights to manage potential trade-offs, promote synergies and increase efficiency (Carbone, 2008; Koff et al., 2020). Given these characteristics, the policy coherence framework has been recognized as a key pillar of the 2030 Agenda for Sustainable Development (Koff et al., 2020). The analysis is based on Nilson's definition of policy coherence, as "an attribute of policy that systematically reduces conflicts and promotes synergies between and within different policy areas to achieve the outcomes associated with jointly agreed policy objectives" (2020, p.396) and will focus on the MERCOSUR – EU Free trade agreement, due to its relevance in terms of trade mechanisms and environmental implications. This qualitative analysis is based on the research desk, focused on the legal documents, and complemented by analysis of policy briefs.

Evidence of EUE in Latin America

To address research question 2 **(RQ4)**, *Is there empirical evidence of Ecologically Unequal Exchange (EUE) occurring in Latin America from 2000 to 2022? Is the Brazilian experience a reflection of a pattern in Latin America?* A semi-systematic literature review is conducted.

Systematic literature reviews are qualitative methods that provide a comprehensive overview of the current state of a subject, allowing the identification of trends, gaps, and further directions for research (García-Peñalvo, 2022). As the empirical evidence of ecologically unequal exchange is limited overall (Althouse et al., 2020; Dorninger et al., 2021b), this method provides a tool to gather the most relevant insights into the occurrence of EUE in Latin America. In addition to identifying evidence and trends of EUA in the region, the objective of this research question is to provide insight that allows us to analyze the most relevant aspects of EUA in the dynamics between Brazil and the European Union and to understand these dynamics in the regional context, becoming an essential section to answer the main research question.

The semi-systematic review was conducted using the Scopus and ScienceDirect databases to identify the most relevant studies. The latest was chosen because initial research conducted in the literature reviews showed a concentration of publications in this database, showing its relevance to the topic. Scopus was selected for its broad reach and relevance in mapping evidence in fields like environment and development (Peters et al., 2015). Following Browne al. (2023) systematic review protocol steps, several steps were followed. First, a list of keywords was developed based on the general literature reviews conducted for this study: ecological unequal exchange, environmental burden shifting, and unequal resource distribution (and its variations).

Second, a structured research string was conducted for each database, with the main criteria of Ecological Unequal Exchange and the geographical limitation of Latin America. The stings are displayed in Table 3. Each research string was adapted to the features of the research tool of each database. In addition to general research for Latin America, each concept string (column 1 in Table 3) was conducted for each country in Latin America. This strategy aimed to identify any relevant country or regional studies.

Table 3:Search Strings used in Scopus and Science Direct databases

Database	Concept 1	Focus Geographical Area	Focus Area Restrictions
Key concepts and scope	Ecological Unequal Exchange	Latin America	Language and relevant fields

Scopus	TITLE-ABS-KEY: • Ecological* AND Unequal AND Exchange • Environmental AND Burden AND Shifting • Unequal AND Resource AND Distribution • Material AND Flow*	AND (Latin* AND America) AND Bolivia OR Brazil, Chile OR Colombia OR Costa AND Rica OR Ecuador OR Honduras OR El AND Salvador OR Guatemala OR Mexico OR Paraguay OR Panama OR Peru OR Uruguay OR Venezuela	AND LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"ECON") OR LIMIT-TO (SUBJAREA,"EART") OR LIMIT-TO (SUBJAREA,"AGRI")) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"ch"))
Science Direct	1.Ecological AND Unequal AND Exchange Title, abstract, key words: Ecological Unequal Exchange	AND Latin AND America AND (followed by the name of each country) Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras,El	Subject Areas Environmental Science Agricultural and Biological Sciences Economics, Econometrics and Finance Earth and Planetary Science

	2. Material Flow Title, abstract, key words: Ecological Unequal Exchange	Salvador, Guatemala, Mexico, Paraguay, Panama, Peru, Uruguay, Venezuela	

The third step consisted of screening titles and abstracts to identify the key studies that provide relevant empirical evidence of EUE in Latin America. The objective of the screening was to distinguish relevant articles from the ones that do not add to the objective of the research. The screening process focused on identifying articles that provided quantitative empirical evidence of EUE occurrence in Latin America, specifying whether the study examined a single country, a group of countries, or Latin America as a region. Additionally, the focus was on determining whether the studies were sector-specific or covered multiple sectors. Studies that appeared in the search results but did not focus on ecologically unequal exchange, those that were qualitative, those targeting specific sub-regions within countries, and those focused on specific materials were excluded from the review. This selective screening ensured that only the most pertinent studies were included, thereby enhancing the relevance of the findings related to EUE in Latin America. Additionally, a time constraint criterion was initially applied, focusing only in studies published between 2000 and 2023. However, application of this criteria was not necessary, as the databases did not display studies from previous years.

C. Strengths and Limitations

Regarding the first method

Regarding the method, one important limitation of MFA is connected to how system´s geographical boundaries are defined (Schaffartzik et al., 2014). This means the specific spatial limits within which material flows are analyzed. Environmental impacts connected to material extraction can go beyond the geographical limitations. Accurately defining these boundaries is crucial to capturing the full extent of these impacts but remains challenging (Schaffartzik et al., 2014; Wiedmann et al., 2015). Moreover, even though MFA provides detailed information on material flows, it often struggles to account for indirect flows and the embodied environmental impacts of traded goods, as it does not inherently include indicators regarding water use, greenhouse emissions, among others (Rivera-Basques et al., 2021). Moreover, MFA lacks integration with economic data and social indicators necessary to understand the extent of the dynamics of unequal exchange.

When it comes to the data, comprehensive and high-quality data are essential for accurate MFA, yet such data can be difficult to obtain, particularly in regions with inadequate data collection systems (Alonso Fernádez & Regueiro-Ferreira, 2022; Rivera-Basques et al., 2021; Muñoz et al., 2011). This is congruent with the data limitations of this study. For example, several commodities in the COMTRADE database had registered monetary values, but not net weight values attached to them. Moreover, 13% of commodities in the COMTRADE registered net weights in values such as "units" or "hundreds of units", which pose an important limitation to understand the biophysical implication, as not further information of the weight of those units is shared. Life stock, such as cows and chickens, for example, are registered with quantification of units, so they were excluded from this study.

Although the systematic literature review provides relevant information for this research, it is vital to recognize its limitations. First, an inclusion bias is linked to the focus on specific academic repositories and the inclusion/exclusion criteria used (García-Peñalvo, 2022)In this regard, due to the nature of this methodology, the inclusion bias also manifests itself in that the search tends to yield research results that support the hypothesis that Ecologically Unequal Exchange (EUE) occurs. Studies that argue that EUE does not occur may not be represented in the search results. Along these lines, a limitation shared among systematic literature studies relates to the complexity of organizing, presenting, and synthesizing findings, including the most relevant information (Peters et al., 2015), in the face of large volumes of literature that meet the inclusion criteria. This limitation does not apply in this literature review, becoming more of a challenge. This is due to the limited literature on EUE that provides empirical evidence, accentuated even more when the geographic scope is regional or specific.

Another relevant limitation is related to the focus on academic literature in English. Given the geographical scope of the research, it is essential to recognize that relevant literature may exist in Spanish or Portuguese. However, this literature is often not reflected in repositories such as Scopus or Science Direct. When searching in Spanish, the results returned do not reflect content related to the subject matter. Given the described limitations, this research section is a semi-systematic literature review.

IV. Results

A. Brazil: a historical overview since the 1950s

The World System Theory underscores the relevance of historical context as a fundamental tool to understand the interconnectedness of global economic and political systems (Chirot & Hall, 1982). History allows us to analyze the foundations of global power structures and how they have permeated into local configurations. In this section, the main features of recent political configurations are revised to gain a deeper insight into the extent and the drivers of EUE in Brazil.

The primary commodity exporter model is familiar in Latin America, rooted in colonial dynamics and intensifying at the end of the 20th century (Infante-Amate & Krausmann, 2019). Brazil has long followed this trend. During colonial times, nuts, rubber, and other forest products, which relied on Indigenous labor exploitation, were the economic base (Bunker, 1984). The late 19th and early 20th-century rubber boom brought significant economic influx but stagnated when rubber demand fell in the mid-20th century (de Sousa Filho et al., 2021). Global structural power dynamics have shaped Brazil's economic specialization from this period onwards.

The commodity-export model intensified during and after World War II due to the high demand for Brazilian commodities (de Sousa Filho et al., 2021). To reduce dependency on the Global North, Brazil promoted import substitution industrialization (ISI) policies in the 1960s and 1970s (Saad-Filho, 2010). "From the beginning, the system of the high level of protection of the domestic market through tariffs, quotas, and the necessity of licenses for imports worked, and Brazil achieved rapid growth of the gross domestic product" (Kocánová, 2020; p. 334). This period, known as the Brazilian Miracle, saw an average of 11.1% GDP growth per year and heavy infrastructure investment but also resulted in significant debt accumulation (Hirschman, 1968; Weaver, 2000).

In the 1980s, Brazil faced a severe debt crisis, fiscal deficits, and triple-digit inflation (Olivera & Villani, n.d.)The crisis stemmed from over-reliance on foreign loans and the oil crisis of the 1970s (Salvador et al., 2020)In response, the World Bank and IMF, under the Washington Consensus, pushed structural adjustment programs (SAP), advocating trade liberalization and reducing industrial protection, which reinforced the commodity exporter model (Kocánová, 2020).

In 1994, the Real Plan was essential in stabilizing Brazil's economy by curbing hyperinflation and stabilizing the currency, heavily influenced by IMF policies advocating free trade and economic specialization (Biljanovska & Sandri, 2018). Deregulation and liberalization emphasized export commodities, enhancing Brazil's status as a major exporter but causing many local industries to close due to global competition (Carneiro, 2010). The economic boom of the late 1990s and early 2000s emphasized raw material extraction and export due to global demand (Barbosa-Filho, 2020). Despite leftist governments' rise in the 2000s, the focus remained on extractivism and commodity exports. The mid-2010s Commodity Consensus, driven by rising prices and Asian demand, altered trade patterns in Brazil (Andrade, 2022), shedding light on alternative trade dynamics and the possibility of South-South cooperation.

During President Luiz Inácio Lula da Silva's early 21st-century tenure, Brazil saw sustained economic growth fueled by a commodities boom. Exports rose by 63.7% between 2001 and 2005, mainly in agriculture, improving living standards and reducing income inequality through consistent social policies (Loureiro, 2018). However, dependence on commodities made Brazil vulnerable to global market changes, leading to economic difficulties from 2011 and fiscal crises under President Dilma Rousseff, culminating in her 2016 impeachment. President Michel Temer's austerity measures led to a slow recovery (Andrade, 2022).

Post-2011 saw economic instability with the end of the commodities boom and corruption scandals like Petrobras. Under President Jair Bolsonaro (2019-2022), natural resources were heavily exploited with minimal environmental protection, and neoliberal policies reduced state economic involvement. Trade shifted towards Asia, but the economy remained reliant on primary exports, vulnerable to price volatility (de Sousa Filho et al., 2021). Investments in technology and infrastructure are crucial to enhancing productivity, employment, and economic stability (Paus et al., 2003)

Brazil's history reveals how power dynamics in the international arena have shaped its internal structures. The primary commodity exporter model has been the basis of the Brazilian economy since the colonial era, enhanced by neoliberalism and the measures pushed by international organizations such as the IMF and the World Bank. The analysis of historical patterns vis-à-vis the EUE will be addressed later in the text. However, it is worth mentioning that international external structures have had a lasting impact on the country's internal conditions, promoting an extractivist model that is not sustainable in the long term.

B. Brazil: the relevance of the case study

Brazil is a crucial case study of how power dynamics in the world system structures shift environmental burdens from the Global North to the Global South, generating ecologically unequal exchange and deepening inequalities. Brazil's relevance as a case study relies on various factors in the economic, geopolitical, and environmental dimensions. In this section, each of these dimensions is explored.

First, Brazil has been an essential player in the global economy, depicting rapid economic growth by integrating Global Value Chains (GVCs) (Biljanovska & Sandri, 2018; de Sousa Filho et al., 2021; Ter-Minassian & Bank, 2012). Brazil has become a key player in the global economy. As of 2022, Brazil was the 11th largest economy in the world by GDP, the 25th by total exports ($341B), and the 26th by total imports (OEC, n.d.; WB, n.d). In general trend, Brazil's GDP has averaged 2.3% annual growth between 2000 and 2022 (WB). In 2022, Brazil's principal exports are beans ($47.2B), crude petroleum ($43.1B), and iron ore ($30.1B), directed mainly to China ($90.1B), United States ($36.6B), Argentina ($15.4B), Netherlands ($11.8B), and Spain ($9.78B) (OEC, n.d). On the other hand, in 2022, imports have focused on refined petroleum ($23B) and motor vehicle parts ($7.96B) (OEC, n.d.; WB, n.d). Details on fluctuations and trend changes will be discussed in the following sections of this research. That said, it is worth mentioning that the 2022 data closely reflects Brazil's economic growth trends and trade dynamics over the past three decades.

Moreover, Brazil's relevance as a case study also lies in the growing geopolitical power the country has gained. Brazil's economic growth has allowed it to diversify its interaction strategies with actors in the global arena, gaining relevance in international and regional organizations. For example, Brazil led the creation of the G20 coalition in the World Trade Organization, placing the "trade policies of developing countries as a central target of the Doha Round" (Stephen, 2014). In addition, Brazil has been at the forefront of regional integration efforts in Latin America, one of the most relevant being MERCOSUR (Common South Market), a political-economic block consolidated in 1994 to promote trade and exchange among the countries in South America. In this line, connected with the country's economic performance, the Global North countries have modified their influence strategy towards Brazil, increasing their regional positioning and facilitating mechanisms to increase their sphere of influence (Burgers 2013). This has positioned Brazil as an emerging power (along with the other BRICS).

Finally, due to the Amazon rainforest's role in global environmental dynamics, Brazil is a crucial case for understanding climate change drivers, dynamics, and mitigation strategies (dos Santos et al., 2023a; Pivello et al., 2021; Tomasella et al., 2023). Brazil is essential to climate change mitigation and adaptation strategies. On one hand, 60% of the Amazon Basin is in Brazil (UN, n.d). This means Brazil hosts the "single largest remaining tropical rainforest and the largest collection of living plant and animal species on Earth" (USAID, n.d). The Amazon Rainforest produces 20% of the world's oxygen and 16% of its freshwater (UN, n.d.), which positions Brazil as a fundamental puzzle in the fight against climate change.

Despite these characteristics, Brazil has yet to transform its structural position and move from the semi-periphery to the core. Stephen indicates that, although there has been a shift in the NG's strategy toward Brazil, Brazil remains excluded from the core in terms of power. On the one hand, it is related to the country's specialization patterns. Since the 1990s, Brazil "imports high-tech goods in general, while going through an early deindustrialization and relying mainly on basic goods for export" (Callegari et al., 2018)Since the 1970s (even earlier, Bunker (1984) would argue, since the colonial period), this dynamic has been marked by exports to the Global North, particularly the United States and Europe, and imports from the Global North. In other words, despite the apparent good economic performance, the country's global structures continue to place it on the periphery.

Moreover, the idea that Brazil has changed its position at the global level, gaining a greater level of power, is challenged. Brazil has become a bridge at the regional level and towards the GS, acting as a "central interlocutor for northern actors trying to cope with pressure from the South" (Burges, 2013, p6). That is, it plays the role of a tool of the NG to advance its agenda in the South. In this line, the level of real influence that rising powers like Brazil can exert in changing the institutions and practices of global governance is limited because their integration into the existing global capitalist system has made them heavily dependent on the Western institutional framework (Stephen, 2014; Lagutina, 2019). That is, Brazil has a level of influence on global structures, but more is needed to modify the game's rules. In this sense, it is positioned in the middle as a semi-peripheral actor, still highly dependent on the NG for its economic development but also to advance its domestic agenda (Schwartzman, 2006).

In environmental terms, despite being a key player in the fight against climate change as it is home to the Amazon, the economy's dependence on raw materials generates tensions between wills and actions. On the one hand, Brazil has been involved in international strategies to combat climate change. In 2023, it played an active role in COP38 and upgraded the emissions commitment through the National Determined Contributions, promising a higher emission reduction percentage until 2030 (Brazil Presidency, 2023). However, the high dependence of the economy on raw materials, together with a diverse extraction pattern focused on both soil and sub-soil-based products, plus intense production of renewable and non-renewable natural resources (Infante Amante et al.,; 2020, Rivera-Basques et al., 202) detract efforts in climate strategies, subrogated under the exploitation activities that seek to generate monetary returns In this context, Brazil becomes a piece of the puzzle to combat climate change and move towards climate justice, which analyzes the EUE, and the displacement of the environmental burden, even more relevant for this country.

C. The economic – environment trade-off

Brazil's economic growth has significantly impacted its environment. The expansion of agriculture and extraction of minerals and fossil fuels has caused environmental degradation, increased droughts, wildfires, water contamination, and biodiversity loss (Carreira et al., 2024; dos Santos et al., 2023a; Loyola, 2014). This section reviews the environmental consequences of resource exploitation for economic growth.

Since 1970, Brazil's domestic resource extraction has risen across all categories: biomass, metallic minerals, non-metallic minerals, and fossil fuels (Figure 1). Biomass extraction, notably high, reflects the country's reliance on commodity exports. From the 2000s, biomass extraction surged due to agricultural expansion, particularly soybean production and cattle ranching, which have been key economic drivers. The agribusiness sector, contributing nearly 25% of GDP, remains robust despite economic downturns (Arima et al., 2021, p1). This sector's economic importance often leads to prioritizing short-term gains over long-term sustainability, causing deforestation and pressure on natural resources.

Brazil's political economy has incentivized a commodity export model, resulting in a Physical Trade Balance deficit, portrayed in Figure 2. This reflects Brazil's role as a net exporter, primarily to Global North (GN) countries, highlighting an Ecologically Unequal Exchange. The metal ore category shows the largest PTB deficit, leading to deforestation, water and soil pollution, and biodiversity loss (Arima et al., 2021; Crouzeilles et al., 2017; dos Santos et al., 2023b). Consequently, Brazil bears the environmental burden, while external actors accumulate resources.

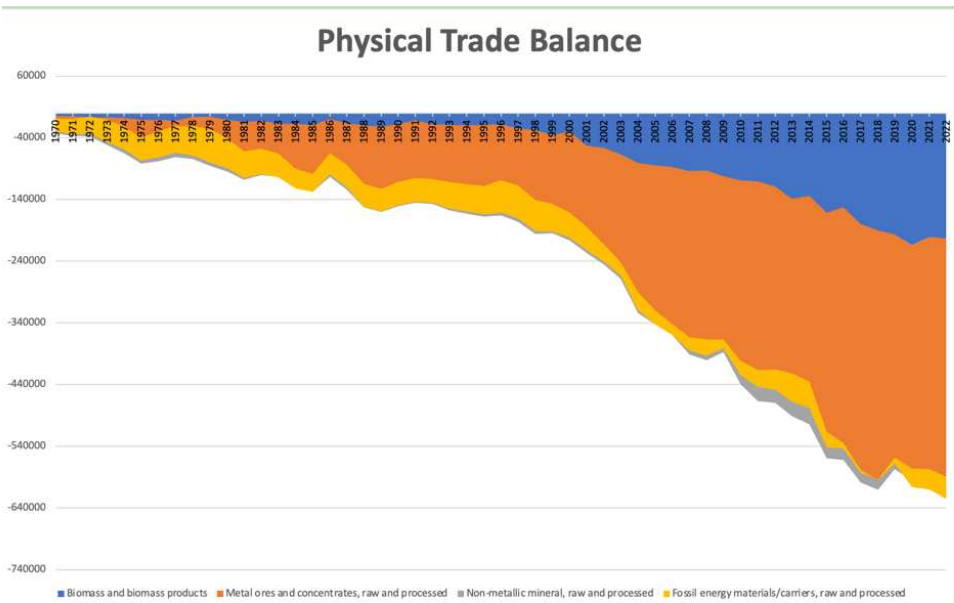

Figure 1: Physical Trade Balance (in thousands of tons) for the period 1970 - 2022.Brazil with the rest of the World. By the author. Source: UN Environmental Program, (n.d).

D. Brazil and the European Union: an ongoing partnership

Historically, the European Union has been one of the main trading partners in Brazil (OEC, n.d). On average for the period 2001- 2022, 18,35% of total exports of Brazil have been directed to EU *(calculated by the author based on data from the OEC, n.d).* Even though since 2007 a shift in the commercial interactions of Brazil took place, when China gained access as one of the main partners, the European Union has remained one the most relevant partners for Brazil. Moreover, even though it has oscillated over time, until 2020, the EU continued to be the biggest foreign investor in Brazil (EU Commission, n.d). In the period 2001-2022, on average, Brazil has represented around 35,7% of the trade of the EU with Latin America.

Moreover, the EU imports from Brazil, are dominated by primary products, including beef, soja, coffee, tobacco, and sugar (OEC, n.d); followed by mineral products, particularly iron ores and ethanol (OEC, n.d). The decade of 2000-2010 was characterized by steady exports focused on agricultural good and raw materials, particularly soy and beef (OEC, n.d). In the decade that followed, agricultural good and livestock continued to be the most relevant product groups, exports on energy embedded materials, such as ethanol and crude petroleum, started to grow significantly. On the other hand, the main imports from the EU to Brazil are machinery and appliances (26.6%), chemical products (23.6%), and transport equipment (13.6%) (European Commission, n.d). Overall, exports towards the EU consist on raw materials and primary commodities, and imports from the EU consist on manufactured goods.

E. Material Flow Accounting between Brazil and the European Union

Following the methodology described in section III, Material Flow Accounting is used to explore possible characteristics of Ecologically Unequal Exchange in the interactions and dynamics between Brazil and the European Union for the period 2001 – 2022. To do so, the Physical Trade Balance (PTB) was estimated, which provides insight regarding the environmental pressures generated through trade, by comparing biophysical exchange through exports and imports. Additionally, the ratio (RI), to understand the difference in traded prices per ton of imports and exports is also estimated. Following Infante Amante et al., (2020), if "to maintain a trade balance equilibrium in monetary terms requires to sell a greater amount of materials than the amount corresponding to the imports, and, therefore, to materially deplete the country or region studied" (p.3). Therefore, this ratio is valuable to explore how additional environmental pressures are developed in a country through trade mechanisms.

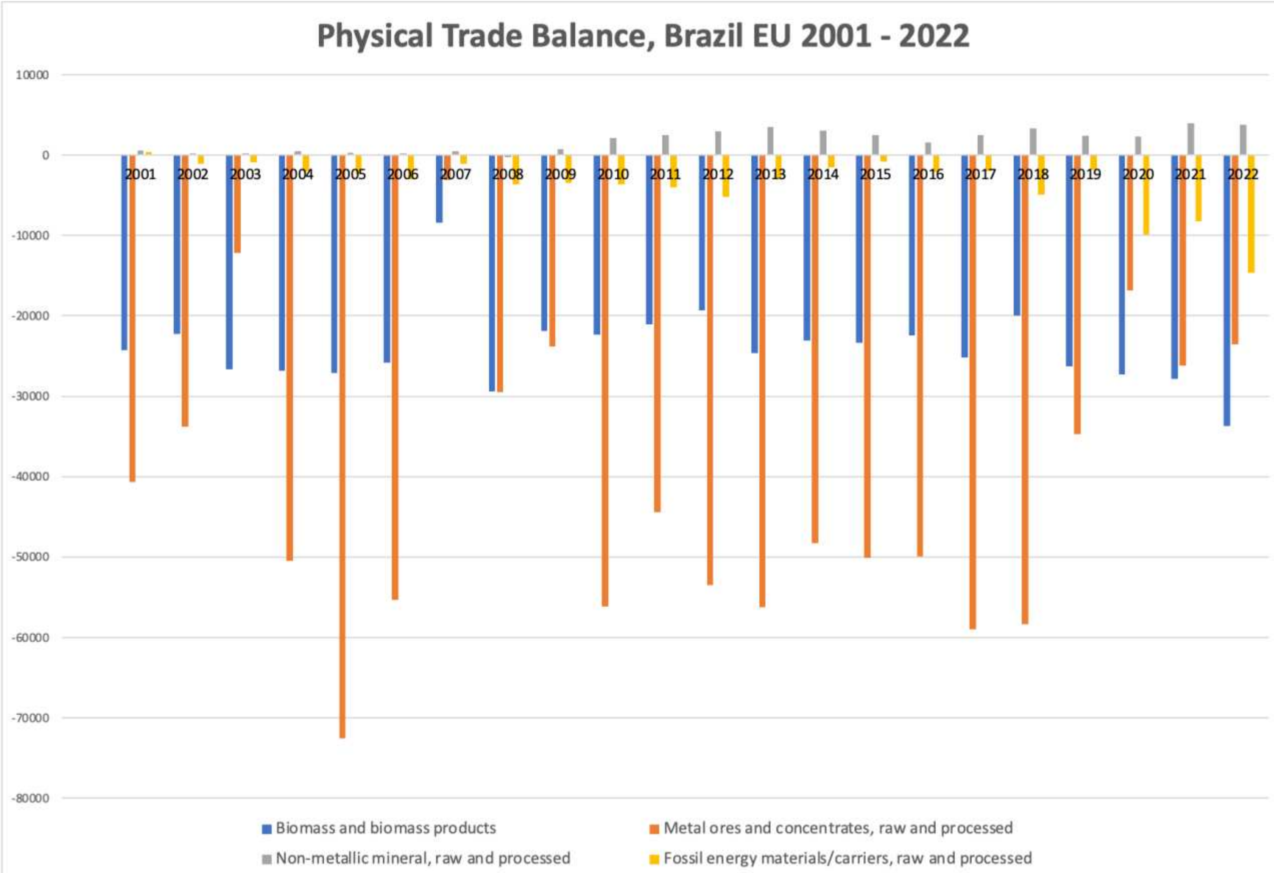

Figure 2:Physical Trade Balance between Brazil and the EU in the period 2001-2022, in thousands of tons. By the author. Source: UN COMTRADE Database, (n.d).

The Physical Trade Balance, in Figure 3, depicts a deficit in the categories of biomass, metal ores, and fossil energies, for all the period studied. This means that Brazil has been a net provider of the commodities embodied in these categories to the EU for the period 2001-2022. Metal ores present the largest PTB deficit in this trade relation. Ores, slag, ashes, as well as iron and steel are among the 10 most exported commodities towards the EU during the studied period, representing, by net weight, 53% of all exported commodities. These results coincide with the findings by Amante and Rivera-Basques et al., 2021, regarding the specialization patters of Brazil.

Moreover, the RI ratio shows important disparities when it comes to the prices of imports and exports. RI for the total physical flow between Brazil and the EU was estimated for the period 2001-2017. 2018-2022 were left out, as data was missing for most commodities regarding traded values disaggregated at commodity level. Values were available only at H2 level of categorization. However, it was decided not to used them because of possible mismatched connected to the categorization of commodities at the H4 level, as some were left out because of lack of information regarding net weights. Bearing this in mind, RI for the total physical flows, was 2,51, which indicates that in average, for this period prices per ton of imports were always higher than prices per ton of exports. Figure 4, shows the variations of prices per material unit measured in current US$ per kilo in the same period. The general trend shows how prices of imports were always higher than prices for exports per material unit.

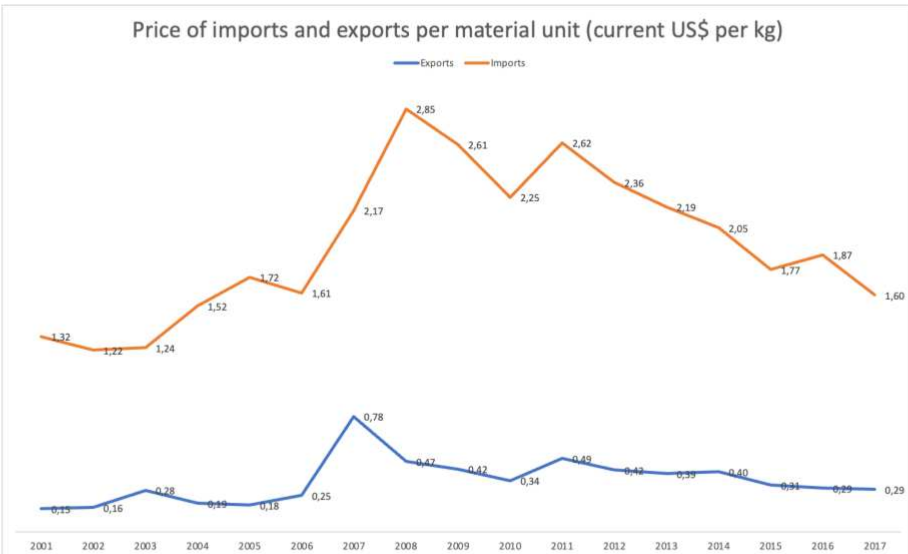

Figure 3:Price of imports and export (current US$ per kg) in trade dynamics between the EU and Brazil for the period 2001 – 2017. By the author. Source: UN COMTRADE Database, (n.d).

Both, the Physical Trade Balance deficit and the RI ratio depict characteristics of Ecologically Unequal Exchange. The PTB deficit regarding metal ores is an indication of Ecologically Unequal Exchange. Metal ores extraction implies important environmental consequences in terms of deforestation (Carreira et al., 2024), as well as water, soil and air contamination (Salvador et al., 2020)depicting environmental burden displacement. At the same time, extraction of metals has been connected to important social struggles, diminishing indigenous populations territories and livelihood (Pransiniewki et al., 2024). Whereas the EU profits of the benefits that the use of materials like iron and steel, broadly use in the manufacturing sector, provide, Brazil is left with important environmental degradation and ongoing social conflict. Moreover, in terms of environmental pressure, the difference of RI ratio could be read as Brazil needing to extract and trade a larger quantity of resources to the EU to be able to meet the monetary trade balance, which mean an increased environmental pressures, as higher quantity of production requires a higher quantity of land, water, and labor.

F. Deforestation: a key sector to understand EUE

Deforestation in Brazil is an ongoing concern, because of all its environmental implications. Since 2001, it has lost more than 6.5 millions of hectares of forest (Forest Watch, n.d). Figure 5, shows the distribution of forest lost over the years in different categories. Commodity driven deforestation is the large-scale deforestation linked to primary commercial activity (Curtis et al., 2018). This means deforestation for the expansion of the agricultural frontier, as well as for the concession of mineral exploitation. Since 2001, commodity driven deforestation has represented 62% of total deforestation in the country.

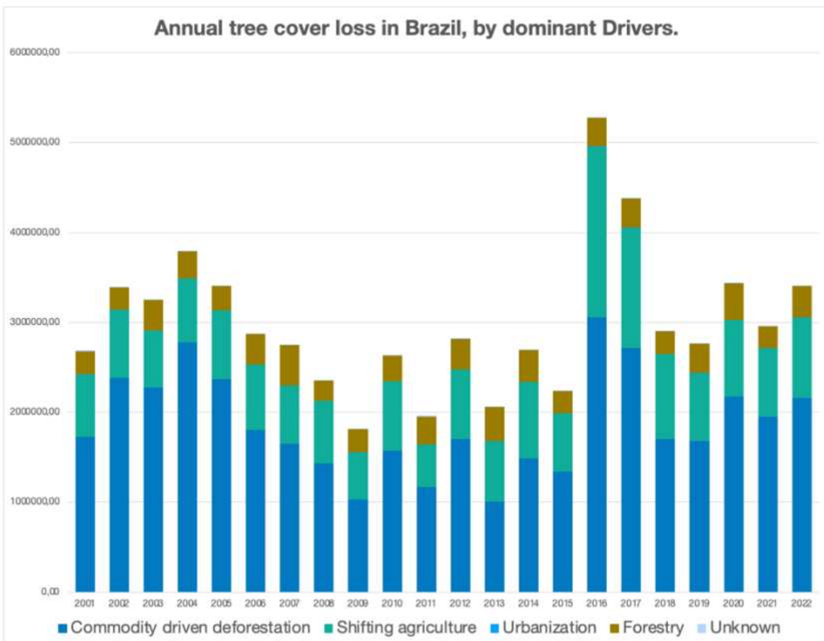

Figure 4: Annual tree cover loss in Brazil, by dominant driver. Period:2001-2022. By the author. Source:Global Forest Wacth (n.d).

Deforestation is connected to CO2 emissions. Brazil IS THE 6TH largest CO2 contributor in the world, and most emission come from deforestation, agricultural and livestock activities (USAID)

In 2023, Brazil updated its deforestation commitment displayed in the first Nationally Determined Contribution (NDC) from 2015 as part of the Paris Agreement, setting a new target to reduce greenhouse gas emissions by 48% by 2025 and 53% by 2030 (initially committed to 43% by 2030) (Brazil Presidency, 2022). However, Brazil frequently implements policies that contradict the global policies it ratifies (Loyola). For instance, the Forest Act, the primary legislation aimed at reducing deforestation, has been revised multiple times in recent decades. These revisions have often extended private land into protected areas, permitting the creation of new hydropower plants and mining concessions (Loyola, 2014)

Furthermore, “deforestation embedded in commodities imported by the EU between 2005–2017 accounted for 16% of the total deforestation in tropical countries during the same period, of which almost one million ha were in Brazil” (Arima et al., 2021, p3). In this line, Arima et al., (2021)explains how soybeans and beef importer alone are the responsible for the loss of 800 hectares of the Cerrado Savannas and the forest in Brazil. Moreover, “approximately 20% of all soy and 17% of beef exported to the EU from the Cerrado and Amazon regions of Brazil are linked to deforestation” (Arima et al., 2021). Deforestation is a clear example of Ecological Unequal Exchange, particularly with the European Union. Moreover, because of the EU free trade agreement with MERCOSUR, in which Brazil plays a key role, there is concerns that commodity driven deforestation, as well as other environmental damages, will rise. In this sense, it is fundamental to look into the EU-Brazil interaction.

G. The Mercosur – EU agreement: implications for EUE

Global trade is responsible from almost two thirds of all human-led material, energy, and land use, as well as deforestation and greenhouse gas emissions (Kehoe, 2020). Ecologically Unequal Exchange is reinforced through trade frameworks that aim to increase resource extraction to meet international demands. "Today, trade is increasingly regulated through international trade agreements, making these agreements a critical means of leveraging action toward sustainability" (Kehoe et al., 2020 p.268). Thus, the revision of regulatory frameworks is essential to understand the extent of Ecologically Unequal Exchange. Because Brazil is part of the Mercosur, and the agreement entails important implications in terms of environmental damage, and EUC, this section follows the methodology described in point III to shed light into this regulatory framework.

Mercosur, or the Southern Common Market, is a regional trade bloc in South America consisting of Brazil, Argentina, Paraguay, and Uruguay. Since its establishment in 1991, Mercosur aimed to promote regional integration, facilitating trade, and the movements of people among its member states (Majchrowska, 2022). After two decades of negotiations, in 2019 an agreement was reached to eliminate tariffs on 90% of the traded goods between the European Union and Mercosur countries (Follador et al., 2021). However, the agreement has not reached its final face and negotiations are still afoot. Despite the current stagnation of the agreement, it poses an opportunity to the possible implications of such a regulatory framework in terms of trade.

While the agreement promises economic benefits by enhancing trade flows, it also poses significant environmental challenges. One major concern is the potential increase in deforestation, particularly in Brazil's Amazon region, driven by the expanded quotas for beef and soy, which are key drivers of deforestation (Kehoe, 2020). Moreover, tariff reductions also include some the metal ores representing the most exports from Brazil to the EU, iron, steel and metal ores, which is displayed on the proposed texts for this framework, in the Appendix on tariff elimination schedule for Mercosur (European Comission, 2022).

Because of these characteristics, and due to the connection between extraction of raw materials and mineral resources, deforestation, and trade, revised before, this agreement possesses potential risks in terms of natural habitat conversion, biodiversity loss, conflicts over land, displacement, and human rights abuses, and further commodity driven deforestation (Boyer et al., 2010; Domingues & Lemos, 2004; Follador et al., 2021; Majchrowska, 2022). In this sense, by increasing the quotas of traded goods, the agreement is creating the conditions and motivations for further extraction and resource depletion in Brazil, reinforcing Brazil position as a net supplier of raw materials and natural resources is reinforced. In terms of the PTB between both countries, this would imply a further deficit, particularly regarding metal ores and biomass, furthering EUE towards Brazil

H. Ecological Unequal Exchange in Latin America: Result of the systematic review

To gain additional insight on how the Brazilian experience is a reflection of the region's experience, and looking to gain further understanding in how EUE is happening in the region, a systematic literature review was carried out to identify empirical evidence of the occurrence of EUEs in Latin America, following the methodology described in section III. And aiming to address RQ4.

The systematic literature review yielded 231 results in the structured research chain. The preliminary results include duplicate articles and studies that must meet the inclusion parameters or contribute something to the research question. Following the methodology described in section III, 81% of the articles were excluded through a first screening process of titles and abstracts. These studies are unrelated to EUE but showed the combination of keywords in the search (e.g., Below 2021 study on land tenure conflict and local community participation). Moreover, duplicates were discarded. Preliminary results showed many duplicates because country-specific searches showed regional or multi-country studies. Of the remaining articles, 35 did not meet the inclusion criteria. These articles were excluded because they provided a theoretical analysis without empirical evidence (e.g., de Janvry's (1975) study on agricultural economics and EUE) or focused on specific sectors or products, such as mining or forestry goods. For example, Smolski and Clark (2024) focused on agricultural dynamics.

After filtering out studies that did not meet the inclusion criteria, a sample of 9 key studies, including research papers and peer reviewed papers, was obtained. Table 4 summarizes the main characteristics of each paper in the sample, and the following section discusses the main findings and insights derived from these studies, contrasting with the case of Brazil.

Table 4: Description of the sample papers retrieved from the systematic literature review.

Authors	Year Publication	Type	Countries	Analyzed with	Period	Methodology	**Variables**
Pérez - Rincón	2006	Case study	Colombia	World	1970–2002	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance
Vallejo	2010	Case study	Ecuador	World	1970-2007	Material Flow Accounting (MFA).	• Domestic Extraction Physical imports and exports • Direct material input Domestic Material Consumption • Physical Trade Balance
Muñoz et al.	2011	Multi-country	Brazil, Chile, Colombia, Ecuador Mexico	United States	2003	Multi regional input -output analysis	• Domestic Extraction • Physical imports and exports • Direct material input Domestic Material • Consumption • Physical Trade Balance

Dorninger and Eisenmenger	2016	Multi-country	Argentina, Bolivia, Brazil.	OECD member countries, excluding Chile, Israel, Mexico, and Turkey.	1962 to 2011	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance • Material Footprint
Samaniego et al.	2017	Multi-country	Argentina Brazil Colombia Ecuador Peru	World	1990 to 2012	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance • Material Footprint
Manrique et al.	2017	Case study	Argentina	Worls	1970-2009	Material Flow Accounting (MFA).	• Domestic Extraction • Direct material input Physical trade Balance • Domestic Material Consumption • Raw Material Equivalents

Alonso-Fernández & Regueiro-Ferreira	2018	Multi-country	Argentina Bolivia Brazil Chile Colombia Ecuador Paraguay Perú Uruguay	China USA EU15	1990-2017	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance
Rivera Basques et al.	2020	Regional	31 LA countries	World, divided in regions	1990 - 2015	Multi regional input -output analysis	• 22 biophysical indicators divided into 4 classifications 1.Land use 2.Water consumption 3.Raw materials 4.Carbon emissions
Infante et al.	2022	Regional	16 LA countries	World	1900-2016	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Raw Material Equivalents
Authors	Year Publication	Type	Countries	Analyzed with	Period	Methodology	**Variables**

Pérez - Rincón	2006	Case study	Colombia	World	1970–2002	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance
Vallejo	2010	Case study	Ecuador	World	1970-2007	Material Flow Accounting (MFA).	• Domestic Extraction Physical imports and exports • Direct material input Domestic Material Consumption • Physical Trade Balance
Muñoz et al.	2011	Multi-country	Brazil, Chile, Colombia, Ecuador Mexico	United States	2003	Multi regional input -output analysis	• Domestic Extraction • Physical imports and exports • Direct material input Domestic Material • Consumption • Physical Trade Balance
Dorninger and Eisenmenger	2016	Multi-country	Argentina, Bolivia, Brazil.	OECD member countries, excluding Chile, Israel, Mexico, and Turkey.	1962 to 2011	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance • Material Footprint

Samaniego et al.	2017	Multi-country	Argentina Brazil Colombia Ecuador Peru	World	1990 to 2012	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance • Material Footprint
Manrique et al.	2017	Case study	Argentina	Worls	1970-2009	Material Flow Accounting (MFA).	• Domestic Extraction • Direct material input Physical trade Balance • Domestic Material Consumption • Raw Material Equivalents
Alonso-Fernández & Regueiro-Ferreira	2018	Multi-country	Argentina Bolivia Brazil Chile Colombia Ecuador Paraguay Perú Uruguay	China USA EU15	1990-2017	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Monetary Trade Balances • Raw Material Equivalents • Raw Trade Balance

Rivera Basques et al.	2020	Regional	31 LA countries	World, divided in regions	1990 - 2015	Multi regional input -output analysis	• 22 biophysical indicators divided into 4 classifications 1.Land use 2.Water consumption 3.Raw materials 4.Carbon emissions
Infante et al.	2022	Regional	16 LA countries	World	1900-2016	Material Flow Accounting (MFA).	• Domestic Extraction • Physical Trade Balance • Domestic Material Consumption • Raw Material Equivalents

In the literature review, there are some main finding worth mentioning.

The physical trade deficit is common in all the studies and all the regions, in all the case studies, regardless of the period of time studies or of the specific interaction studied. This asymmetry translates into a trade deficit also in monetary terms, due to the decrease in export prices of primary goods towards the mid-2010s (Alonso-Fernández & Regueiro-Ferreira, 2022; Vallejo, 2010). The unfavorable relationship of the terms of trade, especially due to the difference in added value between imports and exports, perpetuates dependence on imported manufactured products and maintains unfavorable trade relations (Alonso Fernádez & Regueiro-Ferreira, 2022; Infante Amante et al., 2020; Rivera-Basques et al., 2021; Samaniego et al., 2017; Muñoz et al., 2011).

Massive exports of natural resources such as minerals, biomass and fossil fuels impose a significant environmental burden. This process contributes to deforestation, water pollution and loss of biodiversity, affecting both ecosystems and the health of local populations. The terms of trade often shift environmental burdens to exporting countries, exacerbating environmental degradation in South America.(Pérez-Rincón, 2006; Samaniego et al., 2017b; Vallejo, 2010) Furthermore, the boom in raw material exports has generated socio-environmental conflicts, as local communities resist extractive activities due to their negative impacts (Alonso-Fernández & Regueiro-Ferreira, 2022; Samaniego et al., 2017b; Vallejo, 2010).

Overinvestment in extractive industries such as mining and fossil fuels creates a dependency on these sectors for economic growth, resulting in a net outflow of resources to international markets and affecting domestic economic sustainability. Persistent trade deficits in Latin America require strategies such as increasing exports or external financing, often leading to further environmental degradation (Dorninger & Eisenmenger, 2016; Manrique et al., 2013; Vallejo, 2010). The dependence on extractivism and unfavorable terms of trade reinforce this specialization in the export of basic products, deepening extractivist specialization and exacerbating environmental impacts (Alonso Fernádez & Regueiro-Ferreira, 2022; Samaniego,).

Moreover, socio-environmental conflicts related to land access, environmental degradation and health problems among local populations arise from the rise of raw materials exports. Extraction causes pollution and resource depletion, negatively affecting communities near mineral deposits. Furthermore, ecological inequalities in trade limit the development possibilities of less developed countries, with extractive activities that often have adverse effects on local communities and indigenous populations, leading to socio-ecological conflicts (Alonso Fernádez & Regueiro-Ferreira, 2022; Samaniego,).

There are calls for the transition to post-extractivist economies, advocating for sustainable development and less dependence on natural resource exports (Infante-Amate et al., 2022b; Pérez-Rincón, 2006; Vallejo, 2010). However, the dependence on extractivism under neo-extractivism maintains environmental dependence and its impacts. Policies that promote increased exports or alternative measures to address monetary trade deficits can impact environmental standards and working conditions. Free trade policies and unequal trade relations perpetuate the shifting of the environmental burden from developed to less developed countries, highlighting the challenges in achieving global environmental justice (Alonso Fernádez & Regueiro-Ferreira, 2022).

V. Discussion

Ecological Unequal Exchange focuses on the asymmetric transfers between the Global North and the Global South, through which resource accumulation and exploitation patterns are created ((Althouse et al., 2020; Dorninger et al., 2021; Infante-Amate et al., 2022b)). These asymmetric transfers are rooted in the power the Global North has accumulated in material, economic, and political terms. EUE analyzes how trade dynamics add to the asymmetries of power by promoting a model in which resource-rich countries, such as Brazil, are driven to enlarge and accentuate extraction and exploitation under the promise of economic growth, development, and international integration.

As mentioned in section IV, Brazil reflects a series of tensions and characteristics that make it a critical case study in understanding the theory of Ecologically Unequal Exchange, the power dynamics in which this unequal exchange is rooted, and the environmental implications. If only the economic aspect were analyzed in Brazil, one could say that the theory of unequal exchange ran out of steam. Brazil is one of the most powerful economies worldwide, achieving a crucial monetary flow, incorporating itself into the GVC, and exercising power and geopolitical influence, particularly at the regional level.

However, countries outside the core can accumulate economic wealth. The question is, what does this accumulation imply, and by what means is it achieved? In his study on EUE in Latin America from 1900 to 2016, Infante Amante et al. (2020), mentions that "it is possible to get richer even as a peripheral country. A plausible explanation is that net exports are explained by the countries' endowment of resources and not by their income" (p9). Just because a country increases its wealth does not mean it stops being a net exporter and that its economy depends, therefore, on exploiting resources to satisfy international demands.

The specialization of Brazil, as well as that of Latin America, responds to a path dependency (Patrick, 2020), so throughout the history of Brazil, specialization has focused on raw materials, with several failed attempts to diversify the economy. Away from the modern commodity exporter, towards goods more intense in technology and industrialization. This is reflected in the Physical Trade Balance, both at a general level and in its specific interaction with the European Union; a continuous pattern is seen in which international structures, through trade and under the promise of development and economic growth, lead countries like Brazil, rich in natural resources and raw materials, to depend on extractive and natural exploitation to sustain themselves and mark a route towards a supposed commercial integration with the countries of the Global North. This specialization leads Brazil and the countries of the region to become much more vulnerable to shocks and externalities of the international market ((Samaniego et al., 2017b)), as happened with the oil crisis and the Gulf countries entering the international arena.

Furthermore, as reviewed in section V, the EUE is reflected in Brazil through the PTB's deficits in bilateral interactions with the European Union and with global exchange. These physical deficits are reflected in the monetary deficit of the trade balance (Muñoz et al., 2011). To correct the trade balances in Brazil and the region, governments seek to increase extraction and export, thus increasing environmental pressures. The dispersion of the PTB deficit in different categories exacerbates these pressures. In the case of Brazil, biomass, metallic minerals, and fossil fuels are based on a wide range of raw materials. This implies essential and varied environmental pressures connected to extractive and resource exploitation, including deforestation, contamination of water sources, soil erosion, air pollution, and as a consequence, reduction of biodiversity and increase in the emission of greenhouse gases This shift in the burden of environmental pressures shows the incoherence and double discourse that exists from the countries of the Global North, who, on the one hand, promote development agendas, environmental care, and reduction of greenhouse gases, imposing measures in the Global South. At the same time, they use trade to satisfy their material requirements without having to deal directly with the consequences of this exploitation. At the same time, under this dynamic, the Global North does not expose its resources to depletion, diversifying its trading partners in the South to satisfy its demands and ensuring it will have access to the commodities it requires in the long term.

This dynamic, historically, has been aggravated through trade regulatory frameworks, embodied many times in free trade agreements. Free trade stands out as a significant factor in the exacerbation of the EUE, as it leads to specialization in the production, exploitation, and export of raw materials (with low added value) with high ecological impact towards developed countries specialized in high added value activities with lower ecological impact (Alonso Fernádez & Regueiro-Ferreira, 2022). For example, the Mercosur - EU agreement eliminates tariffs for 90% of goods traded between Brazil and the European Union. Regarding policy coherence, reducing tariffs makes sense to increase trade levels. However, when contrasting this type of regulation with the search for sustainability, the reduction of environmental degradation, and the mitigation of climate change, there needs to be more policy coherence. In this sense, the South has been extremely hesitant about addressing environmental issues in trade negotiations thus far, primarily due to Southern governments' concerns that the North could use environmental regulations as new trade barriers and that environmental issues may divert attention from more urgent developmental needs (Alonso-Fernández & Regueiro-Ferreira, 2022)

In terms of the social implications, EUE, reflected into the extractive model, means conflict and damages for historically underfunded populations. Para las poblaciones indígenas, por ejemplo, las prácticas de deforestación para la extensión de la frontera agrícola implican pérdida de sus livelihoods and ancestral ways of living. Rise in commodity production is directly connected too to social conflict (Kehoe et al., 2020). Indigenous populations, who are usually at the front in the fight against climate change and environmental stewardship, are the first to suffer catastrophic consequences with the expansion of resource exploitation frontiers. These populations, which are already in a state of vulnerability having been historically underfunded and excluded, are exposed to even a higher level of vulnerability when economic activities require an expansion of extractive frontiers. For example, in Brazil, in 2019 alone, 57 environmental leaders, many of whom were indigenous leaders, were murdered (Kehoe et al., 2020). In addition to the violence exerted through exploitation models, the EUE is shifting the consequences of environmental degradation to these populations, who suffer first the consequences of climate change.

Brazil mirrors the structures and patterns created and promoted in Latin America, which position the countries in the region, despite their economic performance, as the suppliers of resources. This implies low material and monetary accumulation, further environmental degradation and depletion, and increasing social and political unrest.

VI. Conclusions & Policy recommendations

This thesis extends the EUE (Ecologically Unequal Exchange) theory by examining trade beyond monetary measures and focusing on resource flows. It investigates trade patterns between the EU and Brazil using Material Flow Accounting (MFA) and situates the results within historical and policy contexts. Historically, Brazil's trade policies have evolved from colonial exploitation, through Import Substitution Industrialization (ISI) strategies, and shifted dramatically following the debt crisis of the 1990s, continuing with increased environmental exploitation under Bolsonaro's administration. This heavy reliance on resource extraction for exports results in economic trade-offs, positioning Brazil as a net exporter to the Global North (GN), with the EU playing a significant role in trade and investment.

The MFA reveals physical trade balance deficits in most categories, indicating that Brazil exports more raw materials than it imports. Additionally, Resource Intensity (RI) analysis shows disparities in the value and impact of traded goods, both reflecting characteristics of EUE that drive environmental degradation and social issues in Brazil. A significant issue highlighted is deforestation, which is exacerbated by partially conflicting policies within Brazil.

The MERCOSUR trade agreement between the EU and South America plays a critical role in this dynamic. By increasing quotas for traded goods, the agreement creates conditions and motivations for further extraction and resource depletion in Brazil, reinforcing Brazil's position as a net supplier of raw materials and natural resources. This export-focused model has deepened Brazil's economic reliance on resource extraction, making it vulnerable to international market shocks and externalities.

Embedding these case study results into the wider academic literature on EUE in Latin America, this thesis includes a semi-structured literature review of nine key studies, confirming asymmetric resource transfers between the Global North and South. This specialization makes Brazil and the region more susceptible to market volatility. MERCOSUR, by encouraging resource extraction, perpetuates this dependency.

This research provides comprehensive insights into the EUE dynamics in Brazil within their historical and political contexts, aligning with broader Latin American trends. For policymakers, two crucial aspects emerge. First, trade policies must consider physical flows and deficits, recognizing their impact on the Earth's system. Models such as planetary boundaries highlight the importance of integrating these physical indicators into trade policy frameworks. Second, policy coherence is essential. For instance, if the EU aims to limit imported deforestation, a single regulation is insufficient without aligning it with free trade agreements and broader trade policies. Similarly, coherence within Brazil's policies is crucial to address environmental and economic challenges effectively.

Future research should delve deeper into the complexities of policy-trade interactions by examining how different stakeholders are affected by trade policies. Additionally, quantitative exploration of EUE dynamics within Brazil could inform the development of targeted policies that address both environmental sustainability and economic stability.

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Annexes

Annex 1: Classification of commodities, following the HS system.

Codification by material, following Eurostat (2018) and UN Environmental Programm.

1. Biomass and biomass products

2. Metal ores and concentrates, raw and processed

3. Non-metallic mineral, raw and processed

4. Fossil energy materials/carriers, raw and processed

5.Manufactures goods

HS category (1 digit)	HS category (2 digits)	Assigned code	HS code
Animal and animal products	Animals, live	1	1
	Meat and edible meat offal	1	2
	Fish and crustaceans, molluscs and other aquatic invertebrates	1	3
	Dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included	1	4
	Animal originated products; not elsewhere specified or included	1	5
Vegetable Products	Trees and other plants, live; bulbs, roots and the like; cut flowers and ornamental foliage	1	6
	Vegetables and certain roots and tubers; edible	1	7
	Fruit and nuts, edible; peel of citrus fruit or melons	1	8
	Coffee, tea, mate and spices	1	9
	Cereals	1	10

	Products of the milling industry; malt, starches, inulin, wheat gluten	1	11
	Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit, industrial or medicinal plants; straw and fodder	1	12
	Lac; gums, resins and other vegetable saps and extracts	1	13
	Vegetable plaiting materials; vegetable products not elsewhere specified or included	1	14
	Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes	1	15
Foodstuffs	Meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof	1	16
	Sugars and sugar confectionery	1	17
	Cocoa and cocoa preparations	1	18
	Preparations of cereals, flour, starch or milk; pastrycooks' products	1	19
	Preparations of vegetables, fruit, nuts or other parts of plants	1	20
	Miscellaneous edible preparations	1	21
	Beverages, spirits and vinegar	1	22
	Food industries, residues and wastes thereof; prepared animal fodder	1	23
	Tobacco and manufactured tobacco substitutes	1	24
Mineral Products	Salt; sulphur; earths, stone; plastering materials, lime and cement	3	25
	Ores, slag and ash	2	26
	Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes	4	27
Chemicals & Allied Industries	Inorganic chemicals; organic or inorganic compounds of precious metals, of rare-earth metals, of radioactive elements or of isotopes	5	28
	Organic chemicals	3	29
	Pharmaceutical products	5	30
	Fertilisers	3	31
	Tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other	5	32

	colouring matter; paints and varnishes; putty and other mastics; inks		
	Essential oils and resinoids; perfumery, cosmetic or toilet preparations	5	33
	Soap, organic surface-active agents, washing preparations, lubricating preparations, artificial waxes, prepared waxes, polishing or scouring preparations, candles and similar articles, modelling pastes, dental waxes and dental preparations with a basis of plaster	5	34
	Albuminoidal substances; modified starches; glues; enzymes	5	35
	Explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations	5	36
	Photographic or cinematographic goods	5	37
	Miscellaneous chemical products	5	38
Plastics/Rubbers	Plastics and articles thereof	5	39
	Rubber and articles thereof	5	40
Raw Hides, Skins, Leather, & Furs	Raw hides and skins (other than furskins) and leather	1	41
	Articles of leather; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut)	5	42
	Furskins and artificial fur; manufactures thereof	5	43
Wood & Wood Products	Wood and articles of wood; wood charcoal	1	44
	Cork and articles of cork	1	45
	Manufactures of straw, esparto or other plaiting materials; basketware and wickerwork	5	46
	Pulp of wood or other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard	1	47

	Paper and paperboard; articles of paper pulp, of paper or paperboard	5	48
	Printed books, newspapers, pictures and other products of the printing industry; manuscripts, typescripts and plans	5	49
Textiles	Silk	1	50
	Wool, fine or coarse animal hair; horsehair yarn and woven fabric	1	51
	Cotton	1	52
	Vegetable textile fibres; paper yarn and woven fabrics of paper yarn	1	53
	Man-made filaments; strip and the like of man-made textile materials	5	54
	Man-made staple fibres	5	55
	Wadding, felt and nonwovens, special yarns; twine, cordage, ropes and cables and articles thereof	5	56
	Carpets and other textile floor coverings	5	57
	Fabrics; special woven fabrics, tufted textile fabrics, lace, tapestries, trimmings, embroidery	5	58
	Textile fabrics; impregnated, coated, covered or laminated; textile articles of a kind suitable for industrial use	5	59
	Fabrics; knitted or crocheted	5	60
	Apparel and clothing accessories; knitted or crocheted	5	61
	Apparel and clothing accessories; not knitted or crocheted	5	62
	Textiles, made up articles; sets; worn clothing and worn textile articles; rags	5	63
Footwear / Headgear	Footwear; gaiters and the like; parts of such articles	5	64
	Headgear and parts thereof	5	65
	Umbrellas, sun umbrellas, walking-sticks, seat sticks, whips, riding crops; and parts thereof	5	66
	Feathers and down, prepared; and articles made of feather or of down; artificial flowers; articles of human hair	5	67
Stone / Glass	Stone, plaster, cement, asbestos, mica or similar materials; articles thereof	3	68
	Ceramic products	3	69

	Glass and glassware	3	70
	Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin	2	71
Metals	Iron and steel	2	72
	Iron or steel articles	2	73
	Copper and articles thereof	2	74
	Nickel and articles thereof	2	75
	Aluminium and articles thereof	2	76
	Lead and articles thereof	2	78
	Zinc and articles thereof	2	79
	Tin; articles thereof	2	80
	Tools, implements, cutlery, spoons and forks, of base metal; parts thereof, of base metal	2	82
	Metal; miscellaneous products of base metal	2	83
Machinery / Electrical	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	5	84
	Electrical machinery and equipment and parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers, parts and accessories of such articles	5	85
Transportation	Railway, tramway locomotives, rolling-stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical (including electro-mechanical) traffic signalling equipment of all kinds	5	86
	Vehicles; other than railway or tramway rolling stock, and parts and accessories thereof	5	87
	Aircraft, spacecraft and parts thereof	5	88
	Ships, boats and floating structures	5	89
Miscellaneous	Optical, photographic, cinematographic, measuring, checking, medical or surgical instruments and apparatus; parts and accessories	5	90
	Clocks and watches and parts thereof	5	91
	Musical instruments; parts and accessories of such articles	5	92

	Arms and ammunition; parts and accessories thereof	5	93
	Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; lamps and lighting fittings, n.e.c.; illuminated signs, illuminated name-plates and the like; prefabricated buildings	5	94
	Toys, games and sports requisites; parts and accessories thereof	5	95
	Miscellaneous manufactured articles	5	96
	Works of art; collectors' pieces and antiques	5	97

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MASTER THESIS

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GLODEP 2024

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MASTER THESIS

Ecological Unequal Exchange. Evidence from Latin America

Paula Daniela CASTELLS CARRION

Supervisor:

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GLODEP 2024

Declaration:

I, Paula Daniela CASTELLS CARRION, declare that my thesis titled " Ecological Unequal Exchange. Evidence from Latin America " is the product of my independent work for the Erasmus Mundus Joint Master Program in Global Development Policy (GLODEP). I confirm that all the content in this thesis is my original work, and I have properly cited, referenced, and acknowledged all academic papers and secondary sources utilized in my research.

____

Paula Daniela Castells Carrion, May 2024

GLODEP

Funded by the Erasmus+ Programme of the European Union

Declaration of honour on the use of AI

During the writing of the submitted thesis, I used the following AI tools, Grammarly, Deepl and ChatGPT to check for spelling/grammatical mistakes, to check/improve my translations and to improve some of my formulations . After using this AI tool, I declare that I have reviewed and edited the text and I take full responsibility for the content of the submitted thesis.

Signature

____

Paula Daniela CASTELLS CARRION

UNIVERZITA PALACKÉHO V OLOMOUCI

Přírodovědecká fakulta

Akademický rok: 2023/2024

ZADÁNÍ DIPLOMOVÉ PRÁCE

(projektu, uměleckého díla, uměleckého výkonu)

Jméno a příjmení:	**B.A. Paula Daniela CASTELLS CARRION**
Osobní číslo:	**R220597**
Studijní program:	**N0588A330004 Global Development Policy**
Téma práce:	**Ecological Unequal Exchange. Evidence from Latin America**
Zadávající katedra:	**Katedra rozvojových a environmentálních studií**

Zásady pro vypracování

The theory of Ecologically Unequal Exchange (EUE) postulates that there are uneven and asymmetric transfers of resources from low-income peripheral countries to high-income core countries in the global trade system, perpetuating economic inequalities and hindering the development of peripheral nations (Dorninger et al., 2021; Hornborg 2019, 2014; Pérez Rincón, 2006; Samaniego et al., 2017). Additionally, EUE relations and the market interactions they entail, increase the vulnerability of peripheric countries to climate hazards and climate shocks (Warlenius et al., 2015). Empirical evidence provided by Hickel et al., 2021; Dorninger et al., 2021; and Infante-Amante & Krausmann, 2019; Althouse et al., 2023; among others, support these claims. This study aims to assess the extent of Latin America's (LA) involvement in Global Value Chains (GVCs) in contributing to EUE with core regions, specifically the European Union, from 2000 to 2015. This research involves analyzing the trade dynamics of biophysical resources concerning GVC involvement and value capture. Moreover, the research intends to examine normative guidelines shaping trade interactions and delve into the socioeconomic and environmental implications of EUE across various LA regions. The research will be used to provide evidence of EUE in Latin America to contribute insights to development discussions and inform policy-making frameworks on addressing inequality and asymmetries in market interactions.

Rozsah pracovní zprávy:	**10-15 000 words**
Rozsah grafických prací:	**as needed**
Forma zpracování diplomové práce:	**tištěná/elektronická**
Jazyk zpracování:	**Angličtina**

Seznam doporučené literatury:

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