



# Uneven development and core-periphery dynamics: A journey into the perspective of ecologically unequal exchange

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## ABSTRACT

There is an imperative need to transition towards sustainable societies to mitigate the consequences of the ongoing social-ecological crisis. This transition not only requires technical advancements, but also the reconsideration of our environmental paradigms and policies shaping the inter-relationships between human societies and natural ecosystems. The perspective of “ecologically unequal exchange” is receiving increasing attention in the academic debate, highlighting the unequal distribution of environmental costs and benefits across different regions, social groups, and generations. This theory posits that such inequalities arise from unaccounted dynamics of global development perpetuated by current environmental and trade policies. Through these, regions of the Core have achieved high levels of consumption and economic growth by exploiting the natural resources and labor of the global Periphery and Semi-periphery, while leaving behind a legacy of ecological degradation, social injustice, and debt. This article contributes to the understanding of ecologically unequal exchange theories, their evolution over time and related implications for sustainability policies. To do so, we perform a bibliometric analysis to assess the evolution and trends of ecologically unequal exchange literature in English-language journals followed by a literature review illustrating the origins of the concept, the theoretical debate, and empirical advances in the field. We find ecologically unequal exchange to be a rising research area with increasing empirical focus, fostered by interdisciplinary collaboration. Moreover, we juxtapose theories of ecologically unequal exchange with the contrasting paradigm of “Ecological Modernization” and the narratives of green growth and decoupling that underpin contemporary global sustainability policies, to elucidate key distinctions.

## 1. Introduction

The belief that trade is beneficial to all parties can be traced back to Ricardo’s theory of comparative advantage and stands at the core of the theoretical justification of neoliberal trade policies (Ricardo, 1821; Ricci, 2019). Mainstream economists argue that mutual agreement in free market exchanges ensures mutual benefits, thus constituting a win-win situation. From such reasoning, markets can be regarded as “ethical systems”, inherently fair and equitable, owing to their adherence to the principle of efficiency maximization (Beder, 2011). The overwhelming consensus among economists on this issue strongly favors trade liberalization policies, making the defense of free trade almost a

sacred tenet of the profession (Krugman, 1987; Krugman et al., 2015; Rodrik, 2018). However, it can be argued that such consensus is the result of a mono-disciplinary and theory-laden view, rather than coming from empirical evidence. Being a product of the so called “economics’ imperialism” in the analysis of global development (Ambrosino et al., 2023), this approach fails to consider the complex and multifaceted implications of trade liberalization (Aistleitner and Puehringer, 2021; Shaikh, 2007). Increasing evidence points at the inconsistencies of such a one-sided perspective, often influenced by self-selection bias, that caused the “overselling of globalization” (Stiglitz, 2017). Empirical findings contest the widely held belief in globalization as a driver of universal prosperity, thereby debunking the myths surrounding the

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concepts of free trade and “catch-up” development (Hickel, 2017a; Shaikh, 2007). Noteworthy is the recent exacerbation of national and international inequalities (Ricci, 2019; 2022), as well as the role played by geographic positioning in shaping income prospects (Milanovic, 2015). The rising tide of global economic growth seems not to lift everyone equally, the associated developmental benefits being unevenly distributed, and this exacerbates inequalities (Hickel, 2017a).

In this context, “ecologically unequal exchange” (EUE) theories offer theoretical and empirical methodologies to underscore the fundamentally inequitable nature of international trade. These theories illuminate the shortcomings of the neoclassical perspective by embracing an interdisciplinary approach grounded on social, economic, and ecological disciplines. Rooted within the broader spectrum of “unequal exchange” (UE) theories (see Section 3), EUE perspectives posit an alternative narrative of international development policies and global inequalities that directly challenges the harmonious “World Bank’s convergence narrative” (Hickel, 2017b). According to EUE proponents, free trade perpetuates persistent divergence in development dynamics rather than facilitating convergence in competitiveness (Rice, 2007a, 2007b, 2009a; Shaikh, 2007). By separating the social and ecological impacts embedded in goods and services from their regions of consumption, international trade reinforces power differentials and exacerbates inequalities. These dynamics ultimately trigger regressive redistributions of global income and environmental resources, with wealth flowing from poorer to wealthier nations (Hornborg, 1998a). Such effects are heightened when international trade links regions with distinct structural characteristics, such as the Core (developed economic centers) and the Periphery (underdeveloped peripheral regions), often mediated by the Semi-periphery, as conceptualized in Wallerstein (1974) model (Fig. 1).

This paper aims to enhance the understanding of EUE theories. The latter can help to uncover the often-overlooked impacts and fallacies (i. e. “Netherlands fallacy”, in Ehrlich and Ehrlich 1990) of current sustainability policies implemented by Core regions, based on “green growth” (Hickel and Kallis, 2020). To do so, we first perform a bibliometric network analysis (BNA) to illustrate research trends, central topics, and influential authors in the field. Results are shown in Section 2. Section 3 delves into the conceptual origins and theoretical discourse of EUE, stemming from diverse critical perspectives (e.g., Marxist vs structuralist approaches to UE, colonialism, dependency theories, etc.). Section 4 combines the BNA and literature review to discuss the state of the art in this interdisciplinary field. We present our conclusions in Section 5.

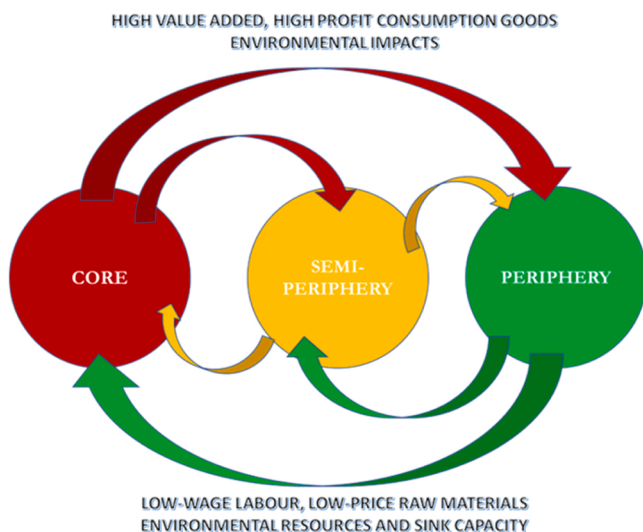


Fig. 1. World Systems' theory model of international exchanges.

## 2. Bibliometric network analysis

### 2.1. Materials and methods

BNA is a quantitative approach based on mathematical and statistical tools analyzing research trends, interrelationships, developments, and impacts in a given research field, allowing a macroscopic overview (Pendlebury, 2008). For this study, the Scopus database was chosen because of its volume of scientific literature contained. Data were collected using the following research string: TITLE-ABS-KEY (“ecologic\* unequal exchange” OR “unequal ecologic\* exchange”) AND LIMIT-TO (SUBJAREA, “SOCI”) OR LIMIT-TO (SUBJAREA, “ENVT”) OR LIMIT-TO (SUBJAREA, “ECON”). The research string resulted in 171 documents, with publication years ranging from 2001 to 2022. The BNA was performed in R using Bibliometrix and its tool Biblioshiny (Aria and Cuccurullo, 2017) and the VOSviewer software, version 1.6.19 (Van Eck and Waltman, 2023).

As BNA relies on content (e.g., keywords, titles, abstracts, etc.), we restricted our search to academic documents written in English to streamline the analysis. Therefore, our findings predominantly reflect Western academia and may not offer a comprehensive global perspective on research pertaining to the topic. This is particularly pertinent for countries in the Global South, where the subject holds significant relevance, yet most publications may not be either in English or in indexed journals. However, we partially address this drawback in Section 3, where we offer a literature review of the theoretical roots of EUE.

### 2.2. Temporal trend analysis and most relevant scientific sources

Fig. 2 presents the evolution in the scientific production on EUE between 2001 and 2022, showing an average 10.8% growth rate. The most frequent documents were scientific articles (78%).

The 10 most relevant sources for scientific publication are presented in Table 1, with *Ecological Economics* being the most common journal (14%), followed by *Journal of Political Ecology* (5.9%), and the *International Journal of Comparative Sociology* (5.3%). The second major source is a thematic book on EUE. Apart from *Ecological Economics*, this research field is rather evenly distributed across other scientific journals.

### 2.3. Most cited documents

The citation analysis of documents is presented in Table 2. Local citation represents the number of citations of a document by other documents within the EUE literature, while global citation represents the total citations of the document. While those articles with higher Local Citation can be considered foundational (i.e., Rice, 2007), the higher Global Citation implies a higher capacity to reach a broader public from different disciplines (i.e., Hornborg, 2009; Muradian and Martínez-Alier, 2001).

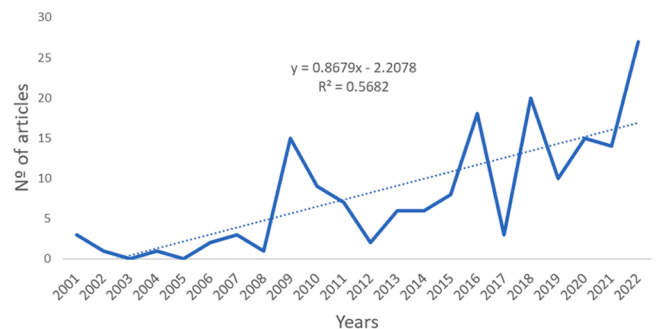


Fig. 2. Temporal trend of scientific articles on EUE.

**Table 1**

The 10 most relevant scientific sources (journals and books).

Scientific sources	N° documents	N° citations	Total link strength
Ecological Economics	24	1095	115
Ecologically Unequal Exchange: Environmental Injustice in Comparative and Historical Perspective	12	90	39
Journal of Political Ecology	10	186	54
International Journal of Comparative Sociology	9	850	115
Capitalism, Nature, Socialism	5	15	11
Journal Of Peasant Studies	4	361	26
Social Science Research	4	296	42
Human Ecology Review	4	98	20
Sustainability (Switzerland)	4	92	40
Journal Of Industrial Ecology	4	67	23

**Table 2**

Most cited documents (10 most cited documents ordered by Local Citation).

Document	DOI	Year	Local Citation	Global Citation
RICE J, 2007, SOC FORCES	10.1353/sof.2007.0054	2007	49	166
JORGENSEN AK, 2006, RURAL SOCIOL	10.1526/003601106781262016	2006	45	192
MURADIAN R, 2001, ECOL ECON	10.1016/S0921-8009(00)00229-9	2001	36	202
GILJUM S, 2004, J ENVIRON DEV	10.1177/1070496503260974	2004	33	152
HORNBORG A, 2009, INT J COMP SOCIOL	10.1177/0020715209105141	2009	30	266
RICE J, 2007, INT J COMP SOCIOL	10.1177/0020715207072159	2007	30	110
JORGENSEN AK, 2009, INT J COMP SOCIOL	10.1177/0020715209105142	2009	29	80
JORGENSEN AK, 2012, SOC SCI RES	10.1016/j.ssresearch.2011.11.011	2012	28	100
JORGENSEN AK, 2016, SUSTAINABILITY	10.3390/su8030227	2016	27	60
SHANDRA JM, 2009, INT J COMP SOCIOL	10.1177/0020715209105143	2009	25	89

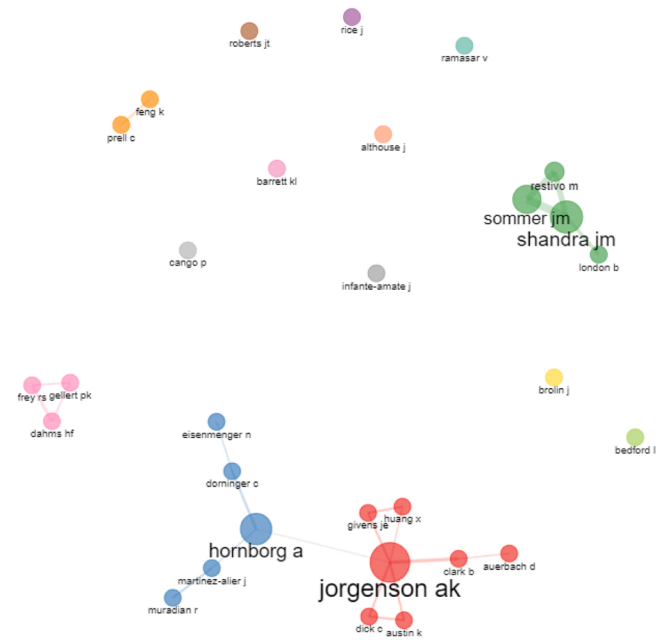
#### 2.4. Research networks on the topic

Regarding the collaboration among researchers, the results show that among the 30 main authors emerged three major clusters of collaboration covering approximately half of authors, and some independent authors (Fig. 3). Despite this limited collaboration found, the co-citation analysis shows that authors co-citation is wide (Fig. 4).

The limited collaboration among authors is also reflected in countries collaboration (Fig. 5). From the 27 contributing countries, USA contributes to 83% of the total documents published, while less than 22% of documents have contribution from the 12 countries of the Global South publishing in EUE. As mentioned above, this may be due to the focus on English-language documents, whereas the main languages used in the South range from Spanish to French.

#### 2.5. Analysis of keywords

Moving from the social and institutional structure to the scientific content, the BNA allows identifying the most used keywords, representing the main topics addressed in the field (Fig. 6). From more than 400 keywords identified, only 21 appear at least in 5 different articles.



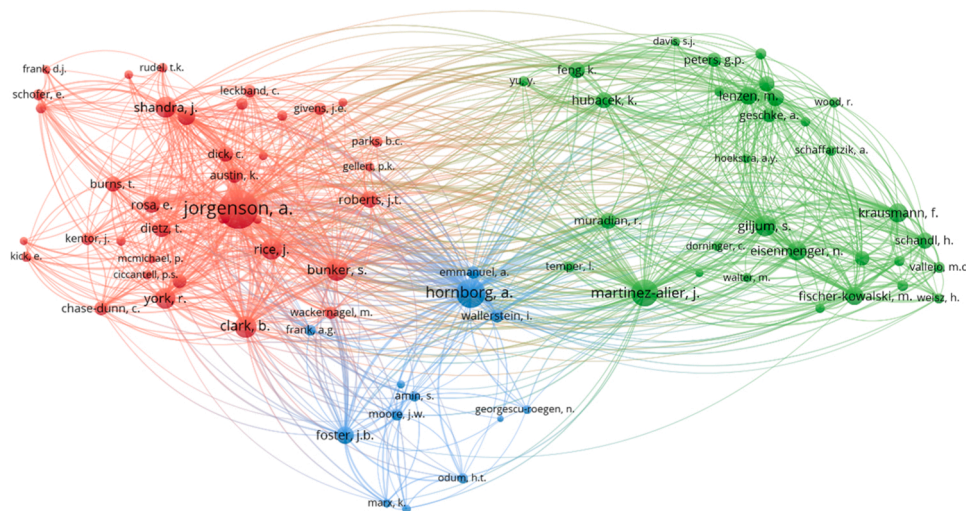
**Fig. 3.** Authors collaboration network. Clusters were calculated using Louvain algorithm, colours were automatically given to different clusters. The size of the nodes depended on the betweenness centrality (the amount of information that node has over the rest).

The closest distance between keywords implies that these terms commonly appear together, therefore conforming different clusters addressing related but distinct scientific topics. Fig. 6 also shows how main topics and research themes connections evolved over time (between 2001 and 2022), using colour gradients that identify the average year of publication of keywords.

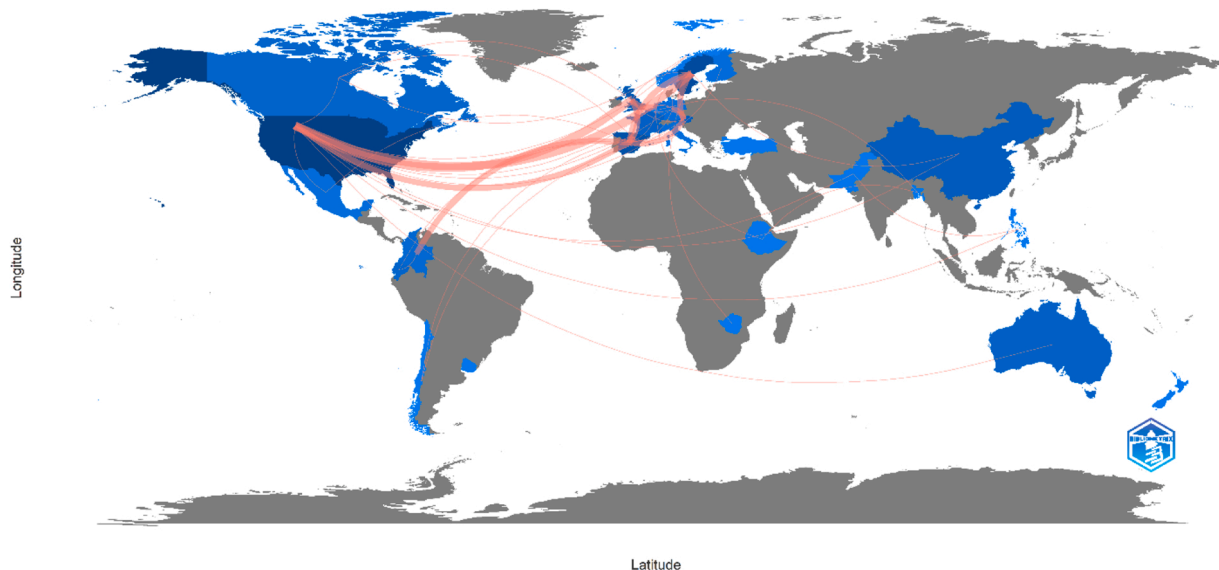
### 3. Scientific background: the roots and theoretical debate on EUE

#### 3.1. Unequal exchange

Throughout history, international trade was long considered a mechanism of exploitation used by powerful empires to accumulate “imperial capital” and hoard value in the form of precious metals (Gokmen et al., 2020). The mercantilist school, under which international trade started to flourish, regarded it as a finite cake where any nation’s gain would come at another nation’s loss (Blaug, 1985; Coleman, 1969). The theoretical debate changed with the rise of Classical Political Economy, focusing on whether free trade constituted a viable mechanism to reciprocally enhance the well-being of nations (Hornborg, 2014; Marx, 1951, 1990; Mill, 1836; Ricardo, 1821; Smith, 1776). Ricardo’s law of comparative advantages emerged from this debate as the core tenet of contemporary international trade policies (Krugman et al., 2015; Ricardo, 1821; Schumacher, 2013). Although overwhelmingly prevailing in the economic doctrine like almost none before (Emmanuel, 1972), these theories can be argued to lack empirical confirmation to a significant extent, to the point that “history of post-war international trade theory has been one of attempting to patch up either the Ricardo [comparative costs] or Heckscher-Ohlin model to fit the facts as we know them” (Shaikh, 2007). This attracted criticism from heterodox economists arguing they are valid only under very restrictive assumptions (i.e., lack of capital mobility, the absence of externalities, etc.) which cannot be considered generally complied in the real world (Fletcher, 2011; Schumacher, 2012, 2013; Siddiqui, 2018). Some scholars have contended that the theory is an expression of the needs of the dominant British Empire at the time, and that Ricardo himself



**Fig. 4.** Co-citation network of authors. A co-citation link depicts two items that are both cited by the same document. The distance between two authors in the visualization approximately indicates the relatedness of the authors in terms of co-citation links. Size of the nodes depends on the number of times that an author is co-cited.



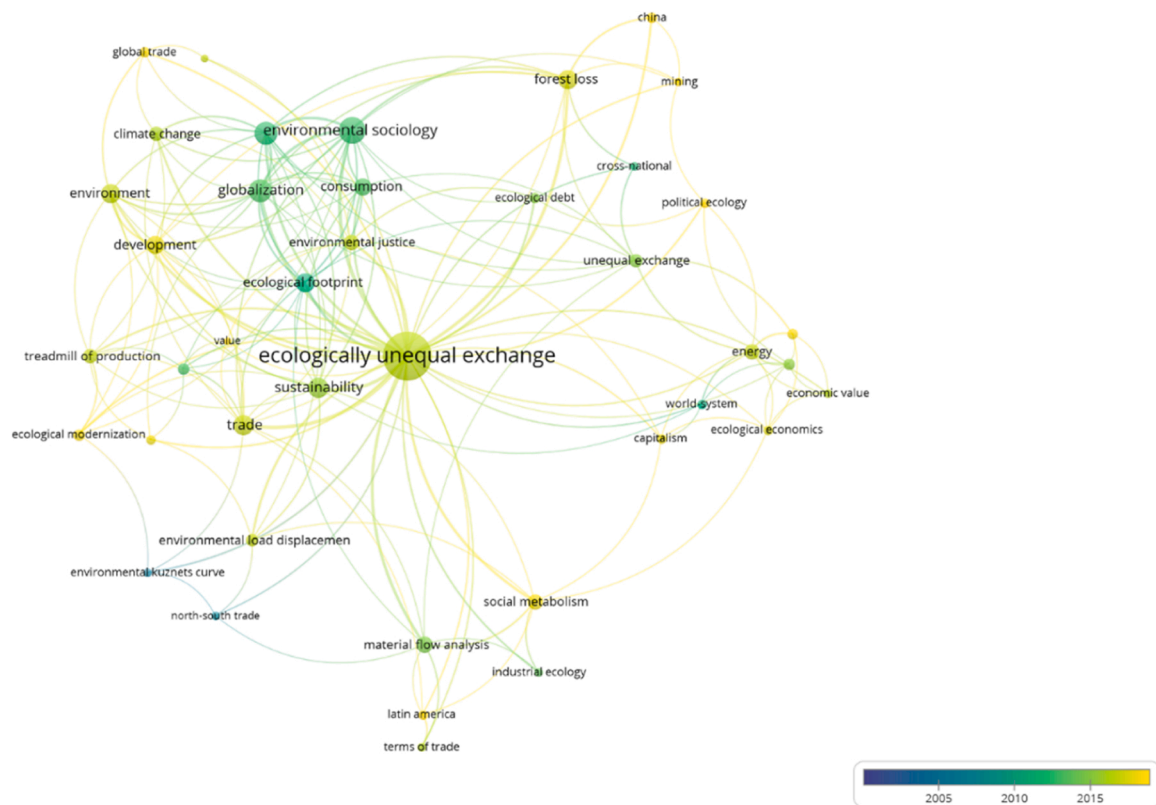
**Fig. 5.** Countries' collaboration world map. Lines link countries that have at least one scientific document in collaboration.

acknowledged the potential for "win-lose" trade relations if significant capital immobility conditions were not adhered to (Fletcher, 2011). In a globalized world where capital freely flows, competitive (absolute) advantages take the place of relative comparative advantages (Daly, 1993). Consequently, opening the backward economies of peripheral regions does not lead to mutual benefits, but to their colonization by the more technologically advanced regions, until "the latter devour the former" (Shaikh, 2007).

The concept of "unequal exchange" belongs to these critical perspectives deeply diverging from the neoclassical paradigm of trade, which extensively relies on the application of Ricardo's law. Throughout the twentieth century, scholars examining commercial interactions between empires and their colonies or former colonies, often underpinned by the maritime and military dominance of the former, contended that trade and development were influenced by power dynamics (Larrain, 1989). Within this framework, international trade is construed as a catalyst for inequality, serving as the primary mechanism for the accumulation of value and overconsumption in advanced regions, thus illustrating the appropriation of value through power imbalances within

the global economy (Roberts and Parks, 2009). Theories of UE were developed to elucidate the imperialistic nature of commercial relations between transnational corporations and economically disadvantaged countries, resulting in the conceptualization of a global value transfer in the form of imperial rent (Hobson, 1917; Lenin, 1950). Subsequently, the concept took its modern form primarily through two distinct theoretical approaches: the Structuralist perspective, associated with the prominent figures of Lewis, Prebisch and Singer (Lewis, 1954; Prebisch, 1959; Singer, 1950), and the Marxist viewpoint, with Emmanuel and Amin as its leading proponents (Amin, 1978; Emmanuel, 1972). From there, "the term unequal exchange became widespread in the 1970 s through Marxist debate on underdeveloped countries and their falling terms of trade" (Brolin, 2007). More recently, Dorninger and Eisenmenger (2016) also point to the roots of UE in the 1970 s and 1980 s world systems and dependency theories, with significant contributions from scholars such as Frank (1966) and Wallerstein (1974). Despite the different theoretical underpinnings, the overarching objective of all UE theories remains the explanation of uneven development through the lens of international trade relations.





**Fig. 6.** Keywords co-occurrence and trend topics in the EUE literature. The size of the nodes is based on the total link strength. This figure represents 41 keywords that appeared at least in 3 different articles. Colours represent the year of publication.

The structuralist approach to UE emphasizes the persistent decline in the terms of trade experienced by less developed countries compared to their more affluent counterparts. This assumption serves as a fundamental premise that numerous scholars have endeavored to demonstrate analytically and validate empirically (Arezki et al., 2013; Harvey et al., 2010). The Prebisch-Singer hypothesis (Prebisch, 1950; Singer, 1950), subsequently integrated into dependency theories (Larrain, 1989) posits that UE originates from the structural characteristics of global markets: countries from the Periphery primarily export raw materials, while those in the Core predominantly export manufactured goods. Manufactured goods exhibit a higher income elasticity of demand than primary products, resulting in a more rapid increase in demand for finished goods as income rises. Furthermore, primary resources demonstrate a low-price elasticity of demand, making it exceedingly difficult for export-intensive periphery countries to boost revenues through price reductions (Shandra et al., 2009a). Emmanuel contributed to this discourse by challenging the notion that the declining terms of trade are solely attributable to the inferior nature of raw materials, highlighting the existence of wealthy exporters of primary products such as Canada, Australia, Sweden or Norway. Emmanuel posited that the root cause lies in the fact that Periphery, regardless of their export composition, “always exchange a larger amount of national labor for a smaller amount of foreign labor” (Emmanuel, 1972). More broadly, for every unit of resources and labor embodied in trade that the Periphery imports from the Core, it must export much more embodied resources and labor to pay for it, enabling the Core to achieve a net appropriation through wage disparities (Amin, 1978; Bernal, 1980; Emmanuel, 1970; 1972; 1975). Rather than equalizing the organic composition of capital, international trade and capital flows work in the opposite direction, perpetuating inequality through a skewed system of incentives where “to him that hath shall be lent” (Emmanuel, 1972; Lewis, 1978). As a result, labor in the Periphery is much cheaper not because it is less productive but because it is more intensively exploited. Within Marxist frameworks, a

notable distinction arises between Emmanuel's and Amin's interpretations. While Emmanuel posited that developed countries, including their working classes, all benefit from UE, Amin contended that only the elite classes reap the benefits, with the working class excluded from the advantages (Amin, 1974; Emmanuel, 1972).

### 3.2. Ecologically unequal exchange

### 3.2.1. Roots of EUE

The concept of EUE has expanded upon the notion of UE towards its biophysical basis (Dorninger and Eisenmenger, 2016). For UE the question was: does international trade promote cross-national disparities in socio-economic conditions through labor exploitation in poor countries? In the context of EUE the question becomes: does international trade promote cross-national disparities in ecological conditions or shape disproportionate consumption of environmental space relative to the position occupied by countries in the world system? (Rice, 2007b). Hornborg links the rise of the concept to an ecologically oriented version of the world systems' theory and dependency theory, together with contributions from ecological economists such as Martinez-Alier on the notion of "ecological debt" (Hornborg, 1998b; Martinez-Alier, 2002). While comprising a diverse array of theoretical frameworks, a unifying characteristic among perspectives within the EUE discourse is the assertion that capital accumulation is not solely contingent upon labor exploitation but also hinges upon the appropriation of ecological resources (Rice, 2007b). World systems' theory postulates that "national development cannot be understood in isolation from the global system where other nations wield greater economic and military power" (Roberts and Parks, 2009). Within this theoretical framework, dependency theories underscore the significance of the Periphery's reliance on Core technology as a primary mechanism impeding the Periphery's prospects for development (Frank, 1966). Dependency theories originated in the 1960 s from the combination of

sociology, politics, historical materialism and economics in the analysis of what scholars considered the dependent situation of Latin America (Frank, 1967, 1973; Furtado, 1966). They are central in the development of both concepts of UE and EUE. The dependency mechanism operates via two primary channels: 1) the Periphery experiences a deprivation of a vital catalyst for development encapsulated in the spill-over effects associated with the production of capital goods; and 2) the elevated cost of technology fosters indebtedness, compelling nations to leverage their available resources—biophysical resources, materials, and sink capacity—in exchange for foreign currency to meet the financial obligations incurred by their expensive imports (Dos Santos, 1970; Frank, 1966; Marini, 1973). The confluence of these dynamics lies at the heart of EUE and is worsened by the aforementioned tendency wherein the Periphery undergoes a persistent erosion of its terms of trade. This implies an ever-increasing amount of primary products export required to keep the same level of imports. The expansion of production in peripheral countries precipitates environmental degradation, including air pollution, deforestation, and water contamination (Roberts and Parks, 2009). External debt obligations and austerity policies often come into play to fuel these dynamics. Structural adjustments required by World Bank or International Monetary Fund demand liberal policies such as privatizations, currency devaluations and trade liberalization (Frey, 2003). Many of these programs “forced developing countries to refocus their economic activities on increasing exports of primary products, mainly through intensified resource extractions” (Warlenius et al., 2015). Developing countries are incentivized to increase the exploitation of their resources to meet these demands, in a sort of “desperation production” which hampers their own development (Arden-Clark, 1992). These dynamics can also cause an oversupply of primary resources on the global market, which further deteriorates their terms of trade and fuels the cycle of dependency (Hornborg and Martinez-Alier, 2016). All these factors perpetuate a flow of resources to the Core, allowing them to maintain high productivity and efficiency, while offloading environmental impacts onto peripheral regions (Dorninger and Eisenmenger, 2016).

### 3.2.2. EUE as asymmetry in biophysical flows

It can fairly be said that the first milestone work on EUE is

“Underdeveloping the Amazon” (Bunker, 1985), which focused on the exploitation of the resources of the Amazon Forest via their incorporation into the global division of labor (Bunker, 1984, 1985, 2003; Bunker and Ciccantelli, 2005). Bunker re-elaborated ideas from Wallerstein’s world-system perspective and Emmanuel’s theory proposing that there was UE also in terms of “energy values” and not only “labor values” (Dorninger et al., 2021; Hornborg, 2014, 2019). The concern extended beyond the mere transfer of surplus value via the declining terms of trade of the periphery. It encompassed the understanding of how path-dependent dynamics, such as extractive activities, influence the societal context—including ecological, infrastructural, and socio-economic aspects—within which subsequent development endeavors are pursued. These dynamics often impede the development of low-income nations (Bunker, 1984, 1985; Bunker and Ciccantelli, 2005). In the words of Bunker: “If energy and matter necessarily flow from extractive to productive economies, it follows that social and economic processes will be intensified and accelerated in the productive economy and will become more diffuse and eventually decelerate in the extractive economy. The flow of energy and matter to productive societies permits the increased substitution of nonhuman for human energies, allows for increased scale, complexity, and coordination of human activities, stimulates an increasing division of labor, and expands the specialized fields of information which this entails” (Bunker, 1985). Hence, EUE is not driven by the extraction of biophysical resources per se, but rather by the social-organizational ramifications triggered between exporting and importing regions (Rice, 2007b). Through asymmetric flows of energy, materials and biophysical resources (Fig. 7), the Core drains resources from the Periphery to maintain its levels of social metabolism, while perpetuating a path-dependent trajectory of underdevelopment in the latter (Hornborg, 2014; Hornborg and Martinez Alier, 2016). This could already be seen in the broad tradition of dependency and world-system theory associated with Baran, Sweezy and Ernesto ‘Che’ Guevara who referred to UE as the way wealth is transferred from poor to rich countries (Foster and Holleman, 2014). Consequently, the progression towards social complexity encounters barriers within the Periphery, whereas the Core benefits from advantageous conditions. Given that socio-organizational complexity serves as a fundamental catalyst for prospective economic advancement, international trade assumes a

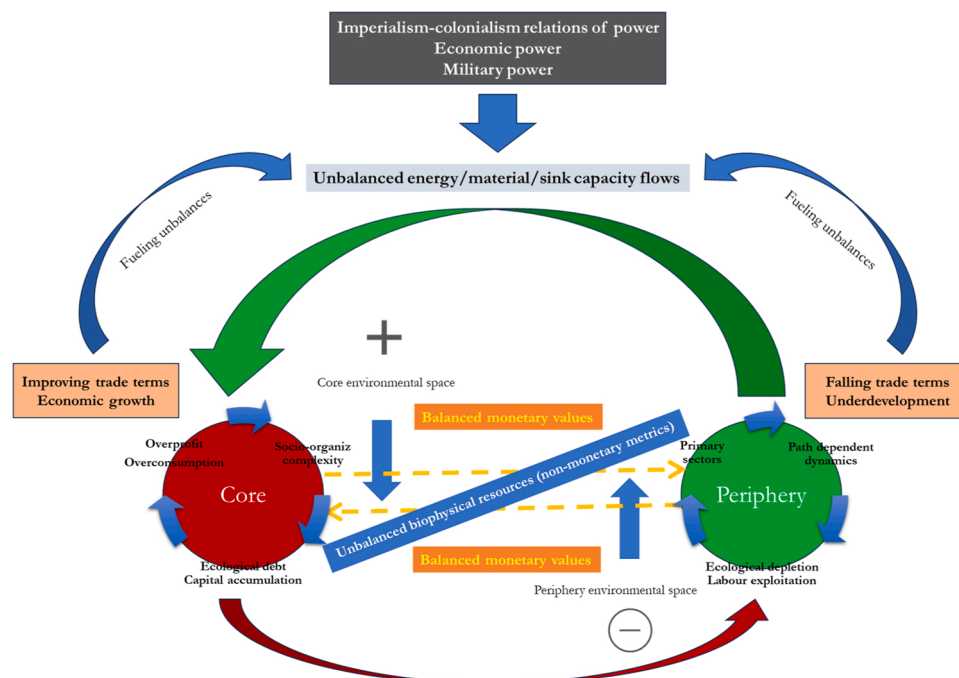


Fig. 7. The many inter-playing dynamics that generate EUE.

role in perpetuating inequality under the guise of economic growth (Hornborg, 1998a). This disparity, while occasionally resulting in increased economic activity in less developed nations due to trade expansion, typically lacks equitable distributional outcomes compared to more developed counterparts. Consequently, impoverished nations often find themselves trapped within path-dependent dynamics characterized by both underdevelopment and socio-ecological disparities (Shaikh, 2007). In this context, EUE theories converge with the “resource curse hypothesis”, which observes that countries endowed with abundant natural resources and significant primary export surpluses often experience developmental setbacks (Papyrakis and Gerlagh, 2004; Sachs and Andrew, 1995).

### 3.2.3. EUE as value appropriation

The asymmetry in flows of energy and biophysical resources between Core and Periphery is accompanied by an asymmetry in value flows. These two perspectives provide different theoretical analyses of the mechanisms underlying EUE, while converging on its outcome: the exacerbation of inequalities (Fig. 7). If the asymmetry in biophysical flows can explain development dynamics, the asymmetry in value flows explains how value is appropriated by the Core. The intrinsic disparities between economic values and the associated biophysical resources delineate distinct domains of knowledge, perpetuating a dichotomous relationship characterized by a “dualistic cosmology” between exchange values and non-monetary metrics (Hornborg, 1998a). Nevertheless, the intricacies of reality, wherein economic, ecological, and physical factors intertwine with social, cultural, and material conditions, necessitate a holistic integration of both perspectives (Hornborg, 2014). While monetary reductionism obscures the asymmetries of the transfers of resources, “the various biophysical metrics provide very important analytical tools to disclose what is going on” (Røpke, 2021). Proponents of EUE argue we should adopt complementary inter-disciplinary value theories, such as those based on ecology (Foster and Holleman, 2014; Odum, 1996; Odum and Odum, 2000, 2001; Brown and Ulgiati, 2004) and the importance of considering thermodynamic laws in economic processes (Georgescu-Roegen, 1971, 1975), which would reveal asymmetries invisible to the mono-disciplinary eye of economists. Seen under the perspective of EUE, international monetary exchanges are never neutral or equal but invariably entail various other forms of exchange. The mechanism underlying value appropriation rely on the recognition that various social and biophysical exchanges integrated into trade possess inherent productive potential, yet lack explicit exchange value - e.g., environmental degradation and socio-ecological impacts embedded in traded products and services - thus remaining unaccounted. Consequently, although monetary exchange values are reciprocal, an inherent imbalance in terms of overall value transfers persists within trade. The greater the “environmental load displacement” enabled by international trade, the greater this unbalance will be (Muradian et al., 2002). The mono-disciplinary approach of economics, dealing only with the monetary aspects of phenomena and equating values with market prices, fails to acknowledge these dynamics. The inter-disciplinary view of EUE, on the contrary, recognizes international exchanges as inherently unequal due to the disparate and multi-dimensional value transfers they encompass between the Core and Periphery. The ecological debt approach to EUE argues that if all environmental and social unpaid costs were accounted for, the financial debt of the Global South could be considered as already fully paid, based “on account of the ecological debt the North owes to the South” (Martinez-Alier, 2002). The inequality lies in the fact that the ecological debt was never accounted for, because contracted in ecological and social metrics, while financial debt is always accounted for because it is measured in money, the universal unit of account in markets. Hence, a proposed solution entails incorporating additional metrics in international exchanges, encompassing social and biophysical dimensions, rather than solely relying on monetary measures to offset the balance of other values (Giljum, 2004).

### 3.3. EUE vs Ecological Modernization: two opposite views

EUE theories represent an alternative view challenging the widespread theories of Ecological Modernization, which argue that wealthier economies can decouple economic growth from material throughput and carbon emissions via resource efficiency gains (Rudel et al., 2011; Schandl et al., 2016). Ecological Modernization objects that citizens of the North are becoming “post-consumerist”: increasingly valuing services and experiences over material products. At the same time, businesses began to incorporate ecological concerns into the core of their operative decisions making, which will lead to green growth and to the solutions of environmental problems; in other words, economy and environment can have synergistic relationships (Mol, 1995; Mol et al., 2009; Mol and Spaargaren, 1993; Simonis, 1989). International trade, in their view, will help spread clean technologies from developed countries to underdeveloped regions, improving at the same time the quality of the environment and the development prospects of poor nations. The Ecological Modernization view has been called a form of “technological utopianism” that can be related to the Environmental Kuznets Curve (EKC) (Hornborg, 2014). The EKC sustains the hypothesis of a U-inverted relation between GDP per capita and economic inequality (Kuznets, 1955) and argues the same hypothesis of U-inverted relation exists between GDP per capita and environmental pollution (Stern, 1998; Usenata, 2018).

According to the EKC (Fig. 8), during early stages of development, environmental pressure rises faster than income growth due to “scale effect”, then it slows down, and after reaching a turning point it finally declines thanks to the so called “composition” and “technique” effects (Usenata, 2018). This idea gained much attraction in the 1980 s and 1990 s arguing that more economic growth and development were good for the environment (Grossman and Krueger, 1995; Selden and Song, 1994). However, subsequent empirical studies increasingly refuted the EKC hypothesis by suggesting that, from a global perspective, the curve takes on a cubic character (i.e. N-shaped), meaning that the decrease in environmental impact is merely temporary or geographically displaced (Jorgenson and Clark, 2012; Leal and Marques, 2022; Stern, 1998, 2004; Parrique et al., 2019). Authors of EUE argue that what explains the observed relative decoupling between growth and environmental degradation is environmental load displacement, which increases the ecological debt of the Core towards the Periphery (Arden and Clark, 1992; Muradian et al., 2002).

Current green growth policies (such as the European Green Deal) which assume that economic growth can be decoupled from material consumption and environmental degradation (Schandl et al., 2016), are clearly a product of the eco-modernist view based on the EKC (Hickel and Kallis, 2020). In this debate, the EUE perspective argues these

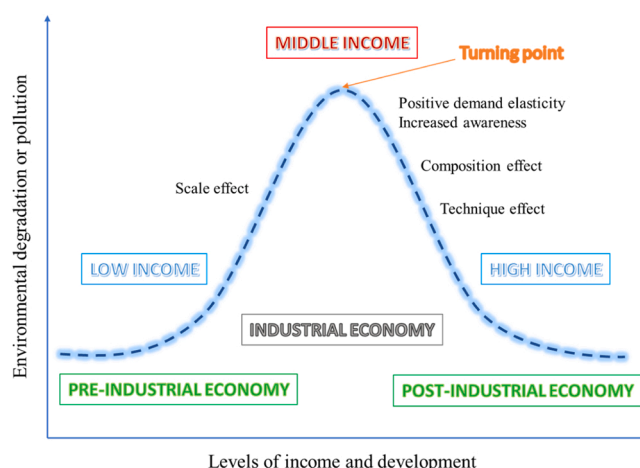


Fig. 8. The Environmental Kuznets Curve.

narratives are instrumental to developed countries' objectives, attempting to sidestep the structural issues of international trade by focusing on a smaller scale. Nevertheless, on a global scale, absolute consumption and the environmental depletion persistently increase, also due to the "Jevons paradox" (Jorgenson and Clark, 2012; Krausmann et al., 2017; Parrique et al., 2019). By importing natural resources while exporting demand for sink capacity, citizens of Core countries may mistakenly perceive their lifestyles as sustainable, as their consumption of environmental space is not directly linked to domestic environmental conditions. The adverse effects of one country's environmental demands may be borne by others, and a systemic examination of international trade may reveal that despite appearances at the national level, a country's ecological footprint may not be necessarily decreasing. For instance, Bringezu and Schütz (2001) showed how EU imports in physical terms were four times its exports, and therefore exports had a monetary value four times higher than imported materials. Thus, "while the EU maintains balanced external trade relations in monetary terms with all other major regions of the world, it runs an enormous trade deficit in physical terms" (Roberts and Parks, 2007). This straightforward recognition provided by material flow analysis dispels the misconception that we have entered an era of dematerialization: the depletion of material and ecological capacity is merely concealed within international trade (Schütz et al., 2004).

## 4. Discussion

### 4.1. Bibliometric evolution of ecologically unequal exchange

The temporal trend analysis of scientific production (Fig. 2) shows that the relevance of the topic of EUE has grown over the last twenty years, although with some discontinuities and abrupt peaks of interest after certain years. A possible interpretation of this trend is that interest in heterodox topics grows steeply after periods of capitalistic crisis and social turmoil (especially 2008, 2016, 2021). Interdisciplinarity and knowledge integration are fundamental tools for the study of the EUE perspective, as evidenced in the analysis of most relevant scientific sources covering a wide range of research areas, from ecological economics to comparative sociology, sustainability science and industrial ecology (Table 1). We believe that the integration of different scientific backgrounds offers a solid approach to the issue, allowing for a cultural analysis of power that enhances the understanding of the EUE perspective.

However, there seems to be a lack of true geographic integration. As mentioned, nearly 80% of publications do not include any author from the Global South. While this can be attributed to our database predominantly covering English-language scientific articles, it also reflects a gap in integration between the global North and South. The co-citation analysis (Fig. 4) shows Hornborg in a central position, linking the other two clusters. Hornborg leads the research area more linked to the theoretical foundations of EUE, near authors like Emmanuel, Amin, and world system theorists (but also early inspirators such as Georgescu-Roegen and Marx). The presence of Odum is interesting since he can be considered a precursor of the concept of UE measured in terms of "emergy" (a measure of the work made by the geo-biosphere) between the Core and Periphery (Brolin, 2007; Odum, 1996). A second cluster includes all the most important authors of empirical and cross-national analyses (Jorgenson, Rice, Shandra, Clark), a research area that builds up on studies regarding the "ecological footprint" concept (Wackernagel and Rees, 1996). In the last cluster of co-citation there are prominent authors within the field of ecological economics such as Martinez-Alier and Muradian, together with authors dealing with the topic from the perspective of societal metabolism (e.g., Dorninger, Eisenmenger, Krausmann) and material flow analysis (Fischer-Kowalski, Giljum), which provide information about the impossibility of fully dematerializing the economy (Haberl et al., 2020; Parrique et al., 2019; Wiedenhofer et al., 2020). In this cluster, it can be noticed also the presence

of the research group focusing on China's EUE led by Feng and Hubacek (Yu et al., 2014).

Finally, the analysis of the keywords (Fig. 6) shows the focus over the years has shifted from a more theoretical approach, with papers revolving around the foundations of EUE, such as "environmental sociology", "globalization", "world system theory", "North-South trade" and "ecological debt", gradually towards a more applied and empirical approach, with keywords such as "forest loss", "China", "climate change", "development" and "Latin America". Also, the tensions between "ecological modernization" and "treadmill of production" theories are clearly visible in the network map (Fig. 6), and still represent a relevant theme in recent years.

### 4.2. EUE as an increasingly empirical research area

Despite being the object of criticism (see for example Agarwala, 1989; Moran et al., 2013; Somerville, 2022a, 2022b), EUE theories appear to be gaining momentum in the academic debate (Villamayor and Muradian, 2023). A major driver is their empirical strength, with an expanding array of methodologies of investigation producing consistent results (Bruckner et al., 2023; Dorninger et al., 2021; Hickel et al., 2022). Our authors' collaboration (Fig. 3) and co-citation analyses (Fig. 4) show that the research field is dominated by authors engaged in empirical assessments of EUE, with Jorgenson in a leading role. Table 2 further validates this thesis. In fact, even if the first positions in terms of global citation are dominated by theoretical analyses (Hornborg, 2009; Muradian and Martinez-Alier, 2001), the two most important documents in terms of local citation are the two empirical studies of Rice and Jorgenson (Jorgenson, 2006; Rice, 2007b). Moreover, these researchers occupy top positions also in the global citation rank, meaning they are not only foundational articles inside the field but also gaining influence on the broader academic debate. According to our citation analysis, 6 out of the 10 most important documents in terms of local citation are empirical and applied studies (Giljum, 2004; Jorgenson, 2006, 2012; Jorgenson et al., 2009; Rice, 2007b; Shandra et al., 2009b), while four are theoretical or review papers (Hornborg, 2009; Jorgenson, 2016; Muradian and Martinez-Alier, 2001; Rice, 2007a).

From the literature review, it can be argued that the first empirical analyses dealing with the topic of EUE were "material flow analysis", becoming quite popular among ecological economists (e.g., Fischer-Kowalski and Amann, 2001; Giljum, 2004). Later, the empirical approach shifted towards "cross-national" research, which was able to investigate the presence of EUE between countries. Among the first cross-national studies were those of Jorgenson who, through the creation of a "weighted export flows" measure, found out that a higher proportion of total exports sent from poorer to wealthier nations was associated with increased rates of deforestation in poorer nations (Jorgenson, 2006, 2008). After Jorgenson's, (2006) study (Jorgenson, 2006), the empirical line of research on EUE started to flourish. A major study employing Jorgenson's cross-national analysis is Rice (2007b), which stands as the most important document in the field (Table 2). It explores the relation between EUE and environmental space consumption (measured by per capita ecological footprint), finding evidence that contradicts neo-classical analysis and confirms the EUE mechanisms. The negative correlation between environmental consumption demand in low and lower-middle-income countries and a greater proportion of exports to the core constitutes evidence of "uneven consequences on utilization of environmental space by country income level" (Rice, 2007b). Moreover, this study suggests that the structure of international trade supports the "polarization rather than convergence of environmental consumption" (Rice, 2007b). Jorgenson brought Rice's conclusions further (Jorgenson et al., 2009) positing that the vertical flow of exports from Core to Periphery is a structural mechanism through which more developed countries can partially externalize their consumption-based impacts on the environment to countries holding a more peripheral position in the world system. It can be argued that these



structural relationships not only contribute to the increase in environmental degradation locally and globally, but also appear to be “directly suppressing resource consumption opportunities for domestic populations, often well below globally sustainable thresholds” (Jorgenson, 2009; Jorgenson, 2012). Subsequent studies with an applied focus reinforced this evidence, showing correlations with several variables, from CO<sub>2</sub> emissions to human health, water pollution or biodiversity (Shandra et al., 2009a; Shandra et al., 2009b). A recent study found evidence that a high quota of exports to the Core (as a proxy for EUE) results in increased mortality rates attributable to air pollution in the Periphery, where “the unequal structure of the global economy and trade system is reifying ecologically unequal exchanges” (Hekmatpour and Leslie, 2022).

Empirical studies on inequalities in international trade and environmental consumption patterns have also employed different methodologies to complement statistical and regression techniques. One example we can mention is the use of emergy analysis (Odum, 1996), which returns similar results. Emergy evaluation points out at inequality in exchanges between Core countries with low emergy:money ratio and peripheral countries with high emergy:money ratio, reinforcing EUE theories. Even if trade is monetary balanced, there is unbalance in emergy flows revealing UE in bio-geophysical terms, that is, all the previous work from nature and society to produce the exchanged products (Cuadra and Rydberg, 2006; Muñoz-Ulecia et al., 2023).

The use of EEMRIO has recently sparked debate among Dorninger, Hornborg, Moran, and their colleagues regarding its suitability as a tool to prove EUE (Dorninger and Hornborg, 2015; Moran et al., 2013). While it can indeed demonstrate a clear separation between regions where resources are extracted (Periphery), processed (Semi-periphery), and ultimately consumed (Core), the use of EEMRIO may lead to some distortions if not applied correctly (Dorninger and Hornborg, 2015). For instance, Moran and colleagues found that United States was a net exporter of biophysical resources, contrary to what is posited by EUE theories (Moran et al., 2013). More recently, Dorninger and colleagues used EEMRIO to highlight deep unbalances and asymmetries in the flows of raw materials, energy, land and labor embodied in international trade, with the Global North as net beneficiary of EUE (Dorninger et al., 2021). Analogous results have been obtained in following EEMRIO studies (Bruckner et al., 2023; Hickel et al., 2022), with Hickel et al. (2022) estimating a cost-shifting of \$242 trillion over the period from 1990 to 2015.

Moreover, the evidence highlighted by EEMRIO analysis seems to hold when applied to “Semi-periphery” countries such as China. Researchers found EUE dynamics (specifically in terms of SO<sub>2</sub>, CO<sub>2</sub>, water, and land) not only between China and importing countries of the Core, but also between China and less developed countries which export large volumes of raw materials to China (Yu et al., 2014). These results further validate the EUE hypothesis.

#### 4.3. Policy implications of the EUE perspective

With the exclusion of prominent but rare exceptions (such as the People’s Agreement of Cochabamba in WPCCC, 2010), there has been very little integration of EUE ideas into policy programs. The political arena is still dominated by a blind faith in free trade and green growth inspired by the EKC (Fig. 8), which underpins global sustainability policies promoted by the Core (Hickel and Kallis, 2020; Hickel and Slamersak, 2022; Vogel and Hickel, 2023). A fully globalized world, according to the mainstream narrative, would constitute an even playing field, allowing the achievement of Sustainable Development Goals (UN, 2015). According to EUE proponents, the reality could not be more different: current inequitable conditions are the result of a colonial and imperial history, which the Global North is retaining by means of international trade and development policies. If the coercive mechanisms were explicit at the time, now they are implicit in the use of geopolitical leverage and economic power to depress labor and resources prices in

the Periphery, causing hidden resource transfers (Hickel, 2022). These unaccounted effects in international trade and development policies are responsible of forging distinctive cross-national burdens and benefits regarding the use and degradation of nature (Dorninger et al., 2021; Jorgenson, 2016; Rice, 2007a, 2009b). Consequently, if the structure of global trade is not changed, development trajectories of Core and Periphery regions will not converge but diverge (inequalities will increase). This is referred as a “zero-sum game”, where the growth of wealthy countries comes at the cost of poor ones, leaving behind the “cornucopia” myth of development and the decoupling narrative (Hornborg, 2009). Under such premises, one cannot believe anymore that the metaphor of “sitting in the same boat” applies to global environmental (and social) issues.

Hence, EUE perspectives have political implications related to systemic and structural changes in global economic governance. Policies should be directed at weakening the capacity of the Core to leverage monopsony and monopoly powers on global supply chains to compress wages in the Periphery’s and appropriate value (Hickel, 2022). In this regard, examples include modifying patents regulation (97% of all patents are held by corporations in high-income countries) and implementing a system of global environmental regulation or universal basic income, to put a limit on labor and resources exploitation (Chang, 2008; Hickel et al., 2022). Political efforts should be directed to democratize the institutions of international economic governance (IMF, World Bank, WTO), where the Core has most votes (and USA holds veto power) although over 80% of the world’s population resides in the Periphery and Semi-periphery (Chang, 2008). In the World Trade Organization (dealing with tariffs, subsidies, and patents), bargaining power is determined by market size, allowing Core nations to set trade rules in their own interests (e.g., tariffs and subsidies removal, elimination of protection for infant industries). These are designed to maximize the drain of labor and resources by the most powerful economies, hindering the industrial development of the Periphery (for example, preventing import substitution policies). Notably, it has been observed that the same rich nations that now demand neoliberal policies refused to comply to these during their early stages of development (Shaikh, 2007). Finally, rather than fueling the illusory myth of “catch-up” development, EUE proponents argue for the necessity of compensatory actions towards the Global South and “scaling down” rich economies (Martinez-Alier, 2002). Some authors promote a de-growth or post-growth approach that recovers the healthy notion of “self-imposed limits” to stop the ecological breakdown and mitigate the irrationalities of modern capitalism (Kallis, 2019). The unlimited pursuit of material growth imposed by capitalism is responsible for the violation of many planetary boundaries to the exclusive benefit of a small minority of global population, as in the case of the “atmospheric colonization” by high-income countries (Hickel, 2020).

#### 5. Conclusions

Our work explores the concept of ecologically unequal exchange (EUE), allowing the identification of its key authors, analytical contributions, and research trends. The theoretical roots of EUE originate in critical perspectives from multiple angles (from anti-colonialism and anti-imperialism to world-system theory, dependency theories and environmental accounting approaches). EUE theories highlight the criticality of multidimensional and multiscale approaches to spotlight the indirect and non-monetary effects of international trade (Guarino et al., 2024 - Preprint). Moving from the theoretical critique of neo-classical economics towards empirical analyses, EUE provides tools to highlight the side effects of current sustainability policies, thus helping to identify complementary or corrective actions. Main empirical outcomes from the literature highlight that international trade leads to unequal exchange in social and environmental terms benefiting Core regions at the expense of the Periphery. Such unfair dynamics, it is argued, are not the result of market failures, but intrinsic features of

capitalism. According to EUE perspectives, growth-oriented policies (as those promoted by the Green New Deal or the European Green Deal) need to be abandoned if sustainability is pursued at the global level, that is, including Periphery and Semi-periphery regions.

### CRedit authorship contribution statement

**Giulio Corsi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Raffaele Guarino:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Enrique Muñoz-Ulecia:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation. **Alessandro Sapio:** Validation, Supervision. **Pier Paolo Franzese:** Validation, Supervision.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data Availability

Data will be made available on request.

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