Unequal Ecological Exchange Analysis of India and the U.K.
WIOT Data Exploration
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Background

Ecological unequal exchange theory is a viewpoint that describes global unequal material and resource exchanges and countries' consequential ecological interdependencies within the world economy. It is grounded in the premise that development and underdevelopment are largely a function of the stratified global system. Ecological unequal exchange can describe the effects of environmentally damaging withdrawal of resources and natural capital, as well as pollution from production, and waste disposal– all of which disproportionately occur within less "developed" countries. These countries often fill a niche within the world economy as a wellspring of raw materials and sink for waste products of further industrialized countries. Unequal exchange theory, previous to ecological unequal exchange theory, has been understood within development and international relations in the context of the undervaluation of labor and deterioration of trade prices. The additional lens of environmental degradation offers a more detailed framework for studying the development paths of different countries and provides a valuable system to understand the complexities of global carbon emissions.

Both unequal exchange theory and ecological unequal exchange theory are rooted in World Systems Theory, which was created and popularized by economic historian Emmanuel Wallerstein. There is no precise definition of unequal ecological exchange theory that is agreed upon by development or international theorists; however, most agree on the following characteristics (Infante-Amate and Krausmann 2019):

- a) asymmetric flow of resources (both biological and other) between nations
- b) outsourcing of the environmental impact associated with extraction and production
- c) unequal "monetary retribution" in trade

Unequal exchange theory offers important information in understanding how the global South is being "drained." Resources such as raw materials, land, labor, and energy

embody the productive potential of a country. Following the flow of all of this capital will lead to the truth about the tilted flow of international trade.

Unequal exchange – whether through capital, resources, labor, devaluation, or pollution – enables a hidden transfer value from the global "South" to the global "North." This hidden cost moves from the periphery to the core, and "takes place subtly and almost invisibly, without the overt coercion of the colonial apparatus and therefore without provoking moral outrage." (Hickel et al. 2022) The asymmetrical power structures that underlie the power of unequal ecological exchange were created by a long history of imperialist and colonialist economics. The overall ambition of colonization was to force the global South into a world economy on completely unequal terms. Unfortunately, not many papers have investigated colonial legacy as the main driver of unequal ecological exchange (Infante-Amate and Krausmann 2019).

With the rise of neoliberal globalization in the 1980s, manufacturing has shifted overwhelmingly to the global "South." Global commodity chains, strengthened in connectivity and direction by neoliberal politics in developed countries, made it possible for developed countries to utilize the power of monopolies in undercutting the prices of products from suppliers in the global South (Hickel et al. 2022). Subsidized exports from the global North and land grabs made by multinational conglomerates consistently undermine the economies of the global South and create downward pressure on wages, devaluing labor for future cheap extraction (Hickel et al. 2021).

Maintaining price differentials in current international trade is in the interest of developed countries, as it ensures that historical patterns of extraction are also maintained. This modern, "post-colonial" extraction is much less overt than its predecessor. With the truth hidden underneath layers of international exchange and devaluation, the blame for "underdevelopment" can be shifted onto the victims.

One method that is used to empirically measure the effects of unequal ecological exchange is an evaluation of international input-output tables (IOTs). IOTs describe the "sale and purchase relationships" between producers and consumers within an economy. IOTs are used in input-output analysis studies that typically focus on estimating the embodied material or pollution in trade and consumption (Peng et al. 2016). In general, there are three types of input-output models used in economics literature: single region

input-output (SRIO) models, emissions embodied in bilateral trade (EEBT) models, and multi-regional input-output (MRIO) models (Peters 2008).

A world IOT (WIOT) is a type of MRIO that describes the sale and purchase relationships between different countries on a global scale. Importantly, a WIOT can be evaluated to find the exact emissions embodied in a single dollar's worth of trade between two countries, down to the specific sector. Using this method, the unequal ecological exchange relationship between a developed and a developing country can be examined. Specific to carbon dioxide emissions, the domestic CO2 emissions created in each country in the production of exports can be compared. If country A is producing greater CO2 emissions per dollar in domestically made exports than country B, that is an unequal relationship.

India belongs to the BRICS (Brazil, Russia, India, China, and South Africa) group of countries that specifically seek to further their economic connection among UN member nations in order to increase their economic and political standing in the world. Since the expansion of international trade to the global South, BRICS countries have become major exporters of manufactured goods rather than natural resources (Peng et al. 2016). India in particular, has been putting major effort into industrializing since the debt crisis of 1991, when the country enacted many neoliberal economic reforms that brought rapid urbanization and economic growth (Sommer et al. 2020). This industrialization was focused on exports and the creation of large manufacturing sectors. India's external debt in 1991 was so large that it brought the country very close to defaulting in meeting international payment obligations. Adopting neoliberal "market-friendly" economic policies to expand export sectors for international consumption was India's way out of the debt crisis, and the global North's way into further resource extraction and devaluation.

Within the colonial context of India as a past colony of Great Britain, ecologically unequal exchange between the two countries should be closely examined not only as evidence of an unequal relationship but also as a continuation of colonial power.

Methods

My input-output analysis was done using the University of Groningen Growth and Development Center's World Input-Output Database (Timmer et al. 2015). Groningen's 2016 spans the years 2000-2016. The data release was an outcome of a project funded by the European Commission. A WIOT can be viewed as a set of national input-output tables that are connected with each other through bilateral international trade flows. By focusing on India and Great Britain, the WIOT was used, with proper analysis and combining of CO_2 emissions data, to represent unequal ecological exchange by a measure of embodied domestic CO_2 emissions per dollar of export (Corsatea et al. 2019).

Written methods:

The WIOT data was formatted to be usable for Python-based analysis, as were the CO_2 emissions data. This involved creating a Pandas DataFrame that contained the WIOT for each year, with proper headers and indexers. Groningen's WIOT data release included a final demand table and total output row, both of which were also reformatted and saved within DataFrames. The Netherlands has no data, so Denmark was used in place, as it is a similar nation in size, location, and trade.

Leontief tables were made from each year's WIOT using the corresponding total output DataFrame. The first step in this process was creating a total requirement table by dividing each cell by its corresponding sector's total output. Then a unit matrix was created to be the exact size of the direct requirement and the WIOT table. The difference between the unit matrix and the direct requirement table was found and saved as a subtraction matrix. The Leontief table was created by inverting this subtraction matrix and was saved as a DataFrame and CSV file for future use.

A master CO_2 table was created using the emissions data from every year and every country's sectors, and then saved as a DataFrame and CSV file. The emissions values were converted from kilotons of CO_2 to tons of CO_2 per dollar by dividing the emissions DataFrame by the corresponding total output value (in million dollars) and then dividing again by 1000.

The final demand values for exports produced in India, being consumed by Great Britain (IND to GBR), and the final demand values for exports being produced in Great Britain, being consumed by India, were identified from the global final demand table and saved as separate DataFrames. India's section of the global Leontief table and Great Britain's section of the Leontief table were separated out and saved as separate DataFrames. For each country, the Leontief table's columns were multiplied by the final demand values for the corresponding final demand value DataFrames (India's Leontief multiplied by IND to GBR final demand values, and vice versa). The Leontief tables were multiplied again by the corresponding direct carbon footprint (in tons of CO_2 per dollar) for each row/sector. This process was completed for each year of data (2000-2014, as the CO_2 emissions data doesn't go beyond 2014).

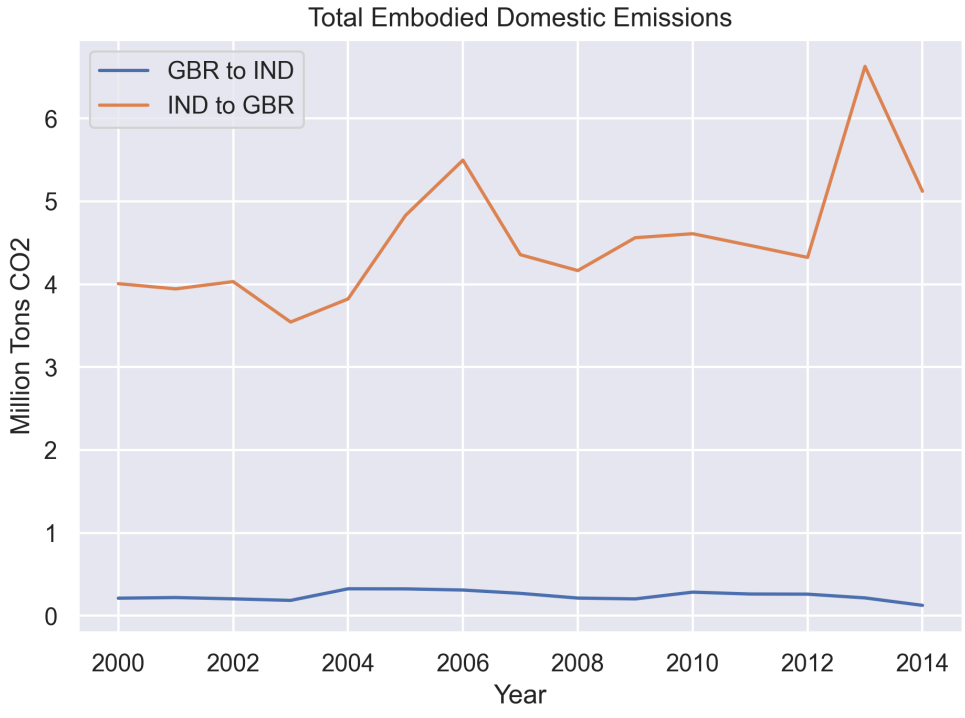
The sum of the entire multiplied Leontief table was taken for both countries, which resulted in an estimate of millions of tons of CO_2 embodied in India's exports to Great Britain and Great Britain's exports to India. The sum of only domestically made exports was also taken, which represented the total domestic emissions embodied in each country's exports. The total domestic emissions for each country were divided by the total value of exports, which resulted in the domestic emissions embodied in India's exports to Great Britain measured in tons of CO_2 per dollar.

Findings

Figure 1

Presented in Figure 1 is the comparison of the total export value between India and Great Britain. There is a clear general positive change over time in the value of India's exports to Great Britain, while the value of Great Britain's exports to India only barely increased throughout the period of record. Between 2004 and 2006, India's exports to Great Britain more than doubled in value. A secondary spike in India's export value to Great Britain took place between 2012 and 2013.

Figure 2



Presented in Figure 2 is a comparison between total domestic emissions embodied in India's exports to Great Britain and total domestic emissions embodied in Great Britain's exports to India. Great Britain has consistently released under 0.5 million tons of CO_2 in export production domestically, whereas India's total emissions never dip below 3.5 million tons of CO_2 throughout the entire period of record. There was also a large increase in total emissions between 2004 and 2006, as well as a spike between 2012 and 2013, both of which are mirrored in Figure 1.

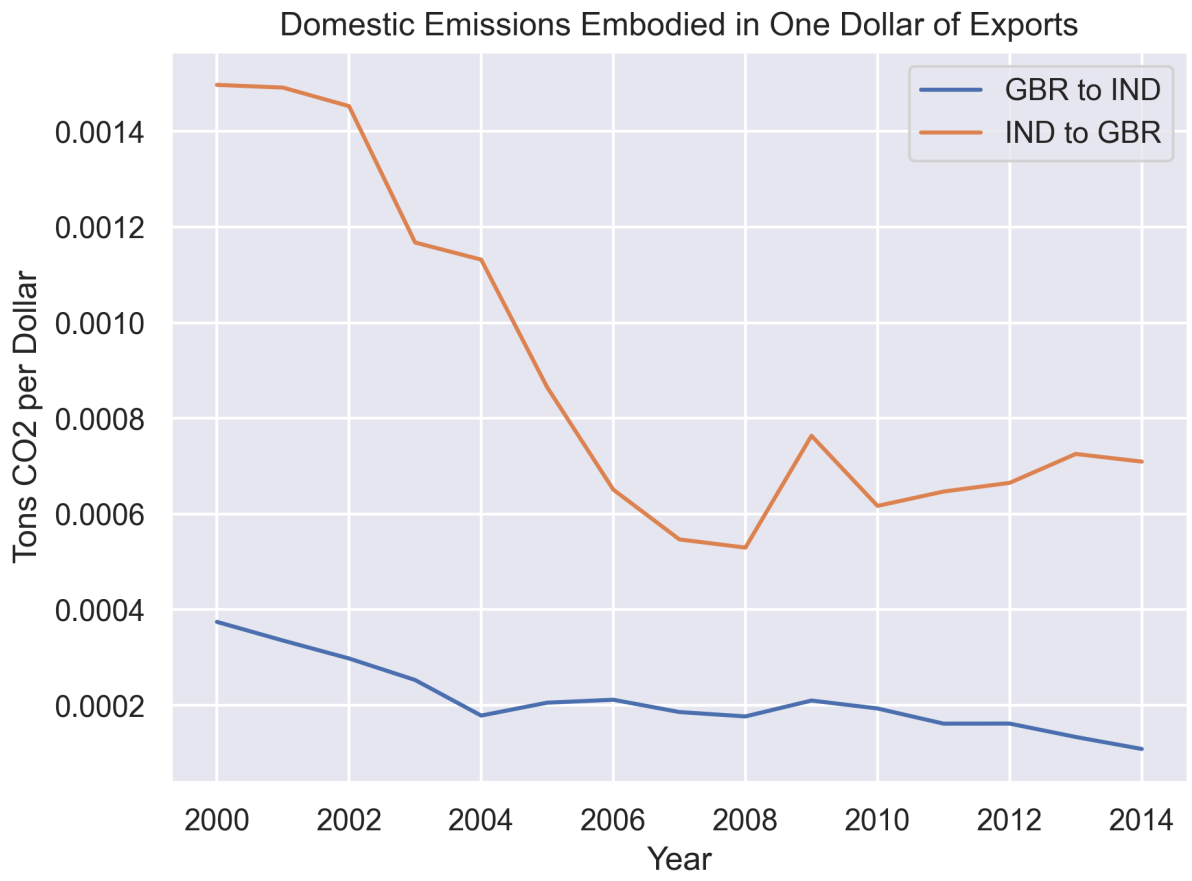


Figure 3

Presented in Figure 3 is the first measure of ecological unequal exchange - the difference in domestic emissions embodied in one dollar of export between India and Great Britain. Once again, Great Britain's domestic emissions never rose above 0.0004 tons of CO_2 per dollar in the entire period of record. India's emission history rarely dips below 0.0006 tons per dollar. There is a strong decrease in tons of CO_2 per dollar in India's domestic emissions between 2000 and 2008, with somewhat leveled emissions rates (between 0.0006 and 0.0008 tons of CO_2 per dollar) after 2010.

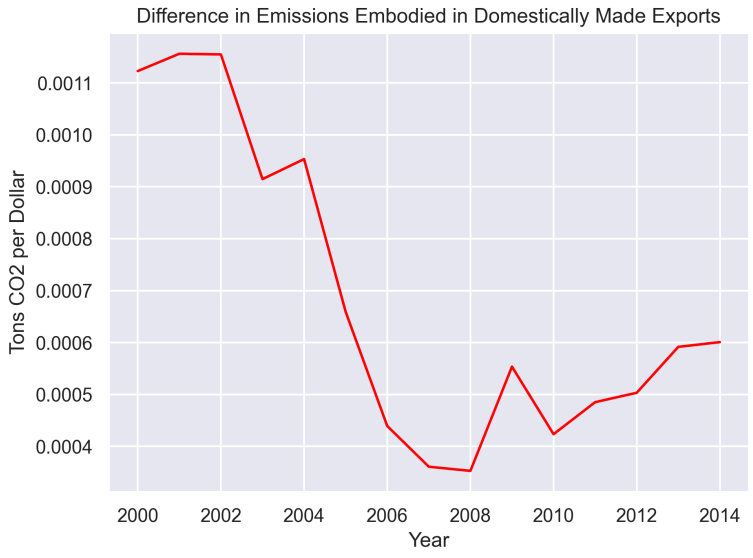


Figure 4

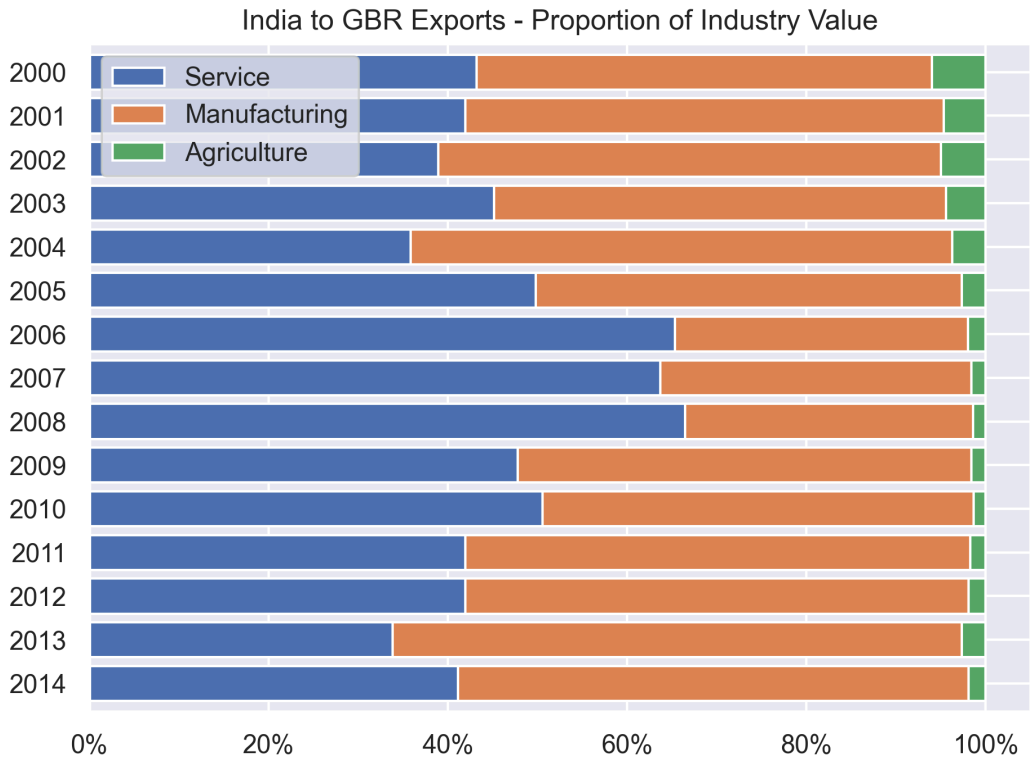
Presented in Figure 4 is a second measure of ecological unequal exchange, measured in the difference between India's and Great Britain's domestic emissions per dollar of export. Clearly, it follows the same trend as presented in Figure 3, but is represented a bit more clearly. The downward trend in the difference in emissions presents a question: what accounts for the steep decline of emissions per dollar over 8 years?

Table 1

INDUSTRY	SECTOR
Agriculture	Crop and animal production, hunting and related service activities
Agriculture	Forestry and logging
Agriculture	Fishing and aquaculture
Manufacturing	Mining and quarrying
Manufacturing	Manufacture of food products, beverages and tobacco products
Manufacturing	Manufacture of textiles, wearing apparel and leather products
Manufacturing	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Manufacturing	Manufacture of paper and paper products
Manufacturing	Printing and reproduction of recorded media
Manufacturing	Manufacture of coke and refined petroleum products
Manufacturing	Manufacture of chemicals and chemical products
Manufacturing	Manufacture of basic pharmaceutical products and pharmaceutical preparations
Manufacturing	Manufacture of rubber and plastic products
Manufacturing	Manufacture of other non-metallic mineral products
Manufacturing	Manufacture of basic metals
Manufacturing	Manufacture of fabricated metal products, except machinery and equipment
Manufacturing	Manufacture of computer, electronic and optical products

Manufacturing	Manufacture of electrical equipment
Manufacturing	Manufacture of machinery and equipment n.e.c.
Manufacturing	Manufacture of motor vehicles, trailers and semi-trailers
Manufacturing	Manufacture of other transport equipment
Manufacturing	Manufacture of furniture; other manufacturing
Manufacturing	Repair and installation of machinery and equipment
Manufacturing	Electricity, gas, steam and air conditioning supply
Manufacturing	Water collection, treatment and supply
Manufacturing	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
Manufacturing	Construction
Service	Wholesale and retail trade and repair of motor vehicles and motorcycles
Service	Wholesale trade, except of motor vehicles and motorcycles
Service	Retail trade, except of motor vehicles and motorcycles
Service	Land transport and transport via pipelines
Service	Water transport
Service	Air transport
Service	Warehousing and support activities for transportation
Service	Postal and courier activities
Service	Accommodation and food service activities
Service	Publishing activities
Service	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
Service	Telecommunications
Service	Computer programming, consultancy and related activities; information service activities
Service	Financial service activities, except insurance and pension funding
Service	Insurance, reinsurance and pension funding, except compulsory social security
Service	Activities auxiliary to financial services and insurance activities
Service	Real estate activities
Service	Legal and accounting activities; activities of head offices; management consultancy activities
Service	Architectural and engineering activities; technical testing and analysis
Service	Scientific research and development
Service	Advertising and market research
Service	Other professional, scientific and technical activities; veterinary activities
Service	Administrative and support service activities
Service	Public administration and defence; compulsory social security
Service	Education
Service	Human health and social work activities
Service	Other service activities
Service	Activities of households as employers; undifferentiated goods- and services-producing activities of households for

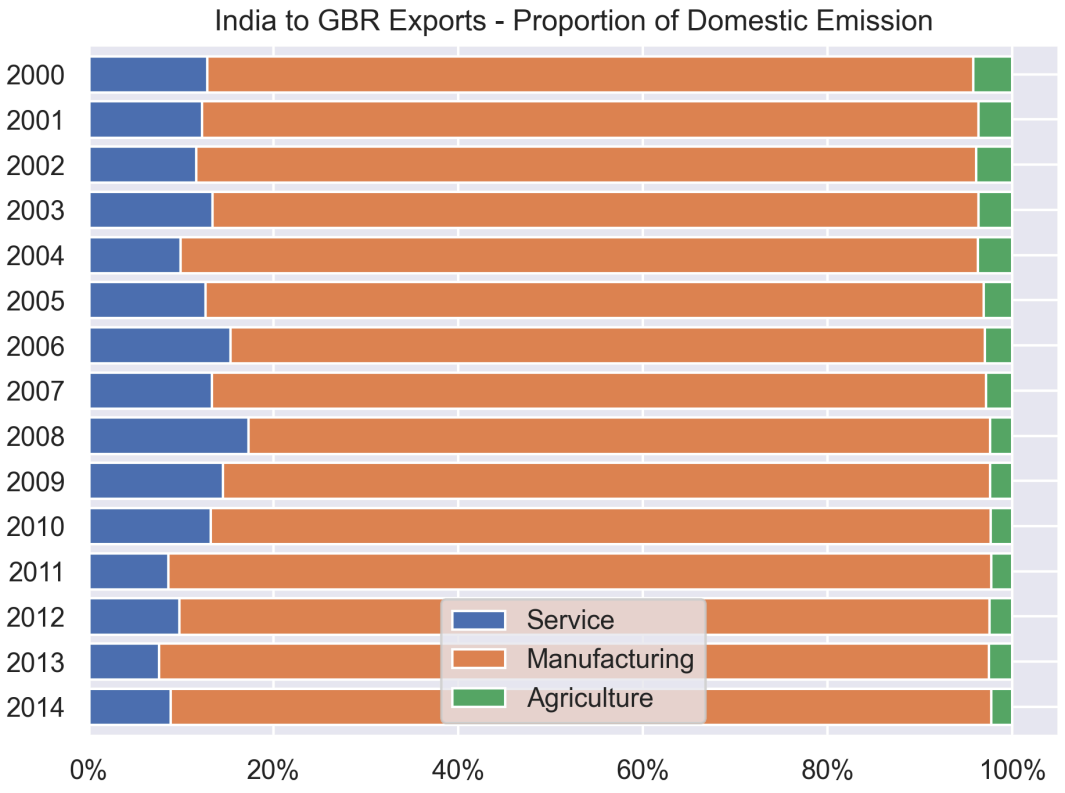
	own use
Service	Activities of extraterritorial organizations and bodies



Presented in Figure 5 is a representation of India's exports to Great Britain broken down by industry. Sectors were divided into industries according to Table 1.

Figure 5

Figure 6



Presented in Figure 6 is a representation of the proportion of domestic emissions in India broken down by industry according to Table 1.

Discussion & conclusion

From the years 2004 to 2006, the total value of exports from India to GBR increased from about $3000 million USD to over $8000 million USD (Fig.1). This can be attributed to the neoliberal economics adopted by both countries that allowed for a great number of resources to be extracted from India as well as the devaluation of the Indian Rupee compared to the British Pound Sterling. Between 2006 and 2008, most were beginning to predict an economic crash, and the value of exports from India to GBR leveled off. During these same years, manufacturing made up less of the total export value than ever before (Fig.5) and CO_2 emissions dropped (Fig.2). Reduction in productivity within the manufacturing sector most likely accounts for the drop in CO_2 emissions. Great Britain, in preparation for the recession, was consuming more from the service industry, which has greater variability of value than the manufacturing industry. In 2008 the recession hit GBR, making both the British Pound and USD plummet in value. GBR then buys fewer exports from India, making the value of exports drop (Fig.1).

The overall downward trend in CO_2 emissions per dollar between the years 2000 and 2008 isn't ultimately clear. One possible explanation is improved efficiency in the manufacturing industry. The proportion of total CO_2 emissions in India from the manufacturing industry doesn't decrease enough to be significant over the years of 200-2008 (Fig.6). However, the value of exports greatly increases over this period. A (relatively) consistent amount of CO_2 emissions divided by an increasing amount of total value would cause the CO_2 per dollar measure to decrease over time.

The importance of further analyses on the ecologically unequal relationship between Great Britain and India, or any colonist country with an ex-colony, cannot be understated. Until recently, most literature on EUE or UEE has focused on GDP as the main explanation, which suggests a direct relationship between EUE and income (Infante-Amate and Krausmann 2019). Understanding the colonial legacy (and present) of EUE is necessary in order to paint a broader, more accurate picture of EUE within the world system. While the results of this study can't definitively point to colonialism as the root cause of India's unequal exchange with Great Britain, they do show that an unequal ecological relationship does currently exist between India and its former colonizer. Future work must be done to examine the relationship between colonialist countries and their former victims.

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