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Exploitation of Natural Resources and Carbon Transfer in Trade



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Forthcoming: Mineral Economics

Blaise P. Likamata

Faculty of Economics and Management, University of Yaoundé II,
Soa, Cameroun

Email: likamatablaise95@gmail.com

Simplice A. Asongu

(Corresponding author)

Department of Economics, University of South Africa,
Pretoria, South Africa

E-mail: asongusimplice@yahoo.com , asongus@afridev.org

Dieudonné Mignamissi

Faculty of Economics and Management, University of Yaoundé II,
Soa, Cameroun

Email: mignamissid@yahoo.fr

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Blaise P. Likamata: Conceptualization, Writing – original draft, Formal analysis, Visualization, Validation, Supervision. **Simplice A. Asongu:** Conceptualization, Data curation, Writing – original draft, Visualization, Validation, Formal analysis, Methodology. **Dieudonné Mignamissi:** Conceptualization, Data curation, Writing – original draft, Visualization, Validation, Formal analysis, Methodology.

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Abstract

This paper analyzes the impact of natural resource exploitation on carbon transfer in international trade, using a severity model estimated by the Pseudo-Poisson Maximum Likelihood High Dimension Fixed Effects (PPMLHDFE) estimator and embodied carbon data from the Enriched Open-Source Multi-Region Input-Output Database (EORA), covering 106 exporting and 114 importing countries over the period 1999–2021. The study demonstrates that natural resource exploitation significantly increases the carbon emissions associated with exported goods. The effect varies according to the type of resource and the income level of the countries, being moderate in low-income economies and more pronounced in middle- and high-income economies. This work contributes to the literature by providing a comprehensive empirical analysis and offering recommendations to guide public policies and industrial strategies toward an effective reduction of embodied carbon while supporting economic development and the energy transition. Policy implications are discussed.

Keywords: Natural resources; carbon transfer; trade

JEL Classification: Q20; Q54; Q56; F10; O31

1. Introduction

The exploitation of natural resources plays a fundamental role in economic activity, but it is also central to environmental concerns. The strengthening of trade integration through the emergence of value chains contributes to the intensification of trade, thereby bringing economies closer together and multiplying trade flows (Zhong et al., 2022). This fragmentation of production improves the competitiveness of economies but is accompanied by an increase in carbon emissions, the main driver of climate change (Desroziers et al., 2025; Wang et al., 2024).

Economic development is closely linked to carbon emissions. To protect the environment, the Paris Agreement on climate change set targets for reducing greenhouse gas emissions while pursuing the goal of sustainable growth. In this context, states have committed through their Nationally Determined Contributions (NDCs), which define national commitments to reduce emissions and promote the energy transition. To this end, economies like Argentina have pledged not to exceed 359 Mt of emissions by 2030 (Saalfeld, 2022). The European Union, for its part, has set a target of achieving a 55% reduction by 2030. Despite this commitment, Lee et al. (2023) show that the efforts implemented are still insufficient to meet the objectives of the Paris Agreement.

However, the exploitation of natural resources could be a factor hindering the achievement of these objectives. The extraction of oil, coal, and minerals, as well as deforestation, generates carbon emissions and other greenhouse gases (Danish et al., 2019). These resources are then transformed or used to produce manufactured goods for international trade, thus contributing to carbon transfer.

Several authors have investigated the factors determining carbon emissions embodied in trade. The literature identifies energy intensity (Shan et al., 2022; Hastuti, 2021); industrial structure (Li et al., 2022; Zhu et al., 2018); sectoral specialization (Su & Ang, 2014; Meng et al., 2018); and dependence on natural resources (Desroziers et al., 2025; Wang et al., 2024) as the main factors influencing the level of carbon embodied in exports. This research shows that highly extractive economies tend to concentrate on carbon-intensive industries, thereby amplifying carbon transfer through global value chains. Furthermore, importing countries indirectly consume the emissions generated by the production of goods in exporting countries. This phenomenon is called embodied carbon.

Analyzing the relationship between natural resource exploitation and carbon transfer is crucial for understanding the mechanisms that influence the environment. This study primarily contributes by examining how natural resources affect carbon transfer across a broad set of countries, addressing a gap in the literature, which has largely focused on single countries like

China (Bai et al., 2025; Tan et al., 2025; Wang and Fujia, 2023) and has overlooked the regional mechanisms linking resource use to carbon emissions.

This paper uses a gravity model adapted to carbon transfer, built from embodied carbon data from the Enriched Open-Source Multi-Region Input-Output Database (EORA database, for 106 exporting and 114 importing countries over the period 1999–2021). The study examines the impact of natural resource exploitation on carbon transfer in international trade. The main findings show that natural resource exploitation leads to an increase in carbon emissions associated with exported goods. Resource-rich countries, where extraction, production, and export are intensive, promote higher carbon transfer. This effect varies depending on the type of resource, with oil appearing as the resource that contributes most to carbon transfer in trade. Furthermore, a country's income level also influences the volume of embodied carbon: the effect is relatively moderate in low-income countries, while it is more pronounced in middle- and high-income economies.

The remainder of the article is structured as follows: section 2 presents the literature review, section 3 describes the methodology employed, and section 4 details the data used. Section 5 presents the empirical results, while section 6 suggests future investigations. Finally, section 7 provides the conclusions and the political and practical implications of the study.

2. Literature review

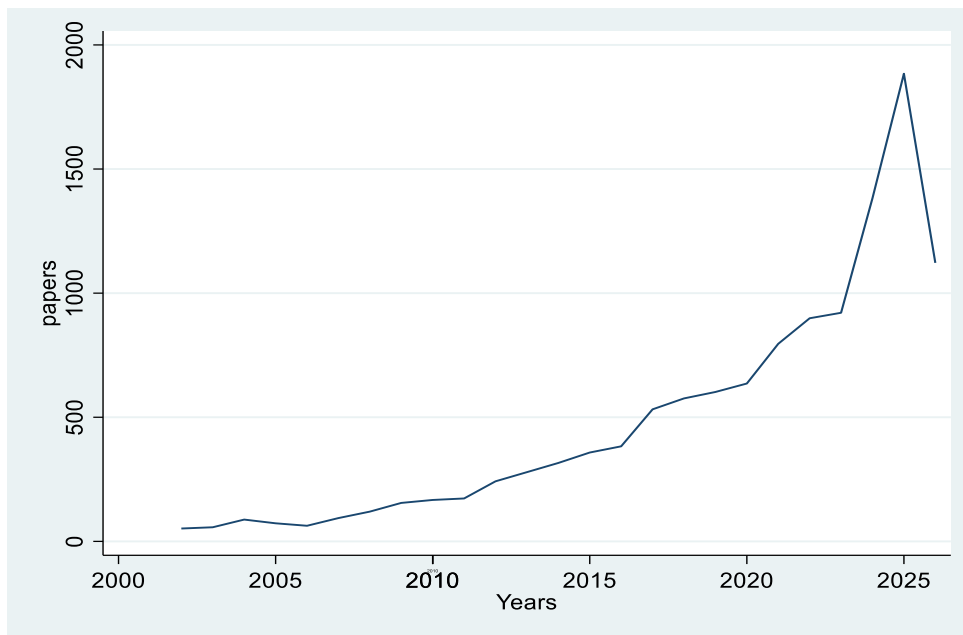
2.1. CO₂ emissions incorporated in commerce

Since the pioneering contribution of Wyckoff and Roop (1994) on carbon embodied in imports from six OECD countries, the issue of carbon emissions embodied in international trade has attracted increasing interest in the literature over the years (Figure 1).

The literature on embodied carbon emissions follows two lines of thought (Liu and Wang, 2025): the first focuses primarily on the quantification of emissions and the second on the determinants or factors that influence them.

In the first area, one of the main theoretical frameworks for analyzing carbon emissions embodied in trade is the *input-output model* (Wang and Fujita, 2023). Initiated by Leontieff (1941), this model measures the carbon embodied in the production of goods intended for domestic consumption and export. Two variants of the *input-output model* are identified in the literature: the single-region input- output (SRIO) model and the multi -region input-output (MRIO) model.

Figure 1: Evolution of the literature on embodied carbon emissions and international trade



Source: Authors, based on ScienceDirect

The SRIO model focuses on carbon emissions generated within a region or country during the production of goods for export and assumes that CO₂ emission factors are identical for all countries (Peters and Hertwich, 2008; Weber et al., 2008). The MRIO model, on the other hand, provides a broader view of carbon emissions by taking into account indirect emissions related

to imports from other countries. Also, unlike SRIO, CO₂ emissions are not identical between countries in MRIO (Yao and Wang, 2025; Wang et al., 2025).

Regarding the second axis, the literature identifies several determinants of trade-embedded carbon emissions. For example, using a gravity model, Sun et al. (2024) and Zhong et al. (2022) identified economic size, geographic location, distance, language, and environmental policy as explanatory factors for trade-embedded carbon. Other studies have analyzed the effects of consumption patterns (Hastuti, 2021), industrial structure (Ribeiro et al., 2023), population growth (Guan et al., 2018), and energy intensity (Peng et al., 2024) on trade-embedded carbon. Liu and Gao (2025) examine the digital channel of trade and conclude that strengthening trade rules could contribute to reducing export-related carbon emissions.

Regarding the determinants of natural resources, Weber et al. (2021) show that economies dependent on rents from natural resources such as coal contribute to intensifying their specialization in this sector and consequently increase emissions when traded. In a more recent study, Desroziers et al. (2025) confirm that oil and natural gas exploitation increases carbon transfer. Moreover, this effect is more pronounced in developing countries. Danish et al. (2019), however, find a mixed effect between natural resources and carbon emissions. Indeed, they arrive at a heterogeneous effect.

The literature also highlights trade liberalization as a determinant of the transfer of carbon emissions between countries (Yang et al., 2025). Trade openness and the removal of trade barriers facilitate the integration of economies into global value chains, enabling specialization in sectors where each country has a comparative advantage (Johnson and Noguera, 2012). However, this liberalization can also have negative environmental repercussions. While liberalization generates economic gains, it can also transfer carbon emissions related to the production of goods to countries with less stringent environmental standards. In this regard, Liu and Gao (2025) emphasize that this dynamic of carbon transfer is particularly pronounced in sectors such as heavy manufacturing and natural resource extraction, where developing countries, often less equipped with eco-friendly technologies, increase their production with high carbon intensity to meet global demand.

Furthermore, the link between monetary arrangements and carbon emissions has been addressed in the literature. Liu et al. (2022) proposed a theory on carbon currency, which envisions global monetary cooperation aimed at reducing carbon emissions. According to their approach, this currency would incentivize countries to adopt stricter environmental policies, as the value of the currency would be directly linked to the climate performance of nations. This could also promote a fairer distribution of environmental responsibilities between producing and consuming countries, reinforcing economic incentives to reduce carbon emissions in international trade. However, while no studies, to our knowledge, have addressed

the impact of monetary unions on emissions and carbon transfer, we explore this perspective in this paper.

2.2. Research gap

Although several studies in the literature have explored the determinants of carbon transfer, there are some shortcomings. These include: *(i)* the predominance of studies at the national level, with a particular focus on China (Wang and Fujia, 2023), which limits our understanding of the global dynamics of carbon emissions; *and (ii)* the lack of in-depth studies examining the mechanisms by which natural resources influence carbon transfer within regional contexts. These shortcomings underscore the need to explore the link between natural resources and carbon transfer.

3. Structural gravity model with fixed effects

3.1. Theoretical framework

The gravity model is suitable for representing bilateral trade relations (Larch et al., 2025). Indeed, it combines, in a multiplicative form, the specificities related to origin and destination as follows in Equation (1)

$$X_{ij} = origin_i \times Destination_j \times T_{ij} \quad (1)$$

Where X_{ij} refers to exports from origin to destination.

Although this specification helps explain trade fluctuations, it lacks a theoretical foundation. Several studies in the literature provide a theoretical basis. For example, Anderson (1979) and Anderson and Wincoop (2003) derive the gravity equation from a monopolistic competition model; Earton and Kotum (2002) draw on the Ricardian model; and Costinot et al. (2012) use a Ricardian sectoral model.

In the context of this work, following the work of Freeman et al. (2025), we retain the structural gravity equation of Anderson and Wincoop (2003) specified as follows in Equation (2):

$$X_{ijt} = \frac{Y_{it}E_{jt}}{Y_t} \left(\frac{t_{ijt}}{\Omega_{it}\Phi_{jt}} \right)^{1-\sigma} \quad (2)$$

Where Y_{it} information is provided on the exporter's production level; E_{jt} the importer's expenditures; Y_t global production; t_{ijt} captures bilateral trade frictions. Ω_{it}, Φ_{jt} These are the multilateral resistance terms for the exporter and importer, respectively. σ Denotes the elasticity of substitution and $1 - \sigma$ the elasticity of trade.

Applying the log-linear transformation, Equation (2), including the error term, ε_{ijt} becomes Equation (3) as follows:

$$\ln(X_{ijt}) = \ln Y_{it} + \ln E_{jt} - \ln Y_t + (1 - \sigma) \ln t_{ijt} - (1 - \sigma) \ln \Omega_{it} - (1 - \sigma) \ln \Phi_{jt} + \varepsilon_{ijt} \quad (3)$$

3.2. From theory to empirics

Equation 3.3 provides a theoretical basis for representing the relationship between bilateral exports and structural variables. Our objective is to analyze the effect of natural resource exploitation on the transfer of carbon embodied in exports. Following the recommendations of Santos Silva and Tenreyro (2006), we use the PPML estimator, which overcomes the limitations associated with estimating the model using OLS in its log-linear form. These limitations include the heteroscedasticity of bilateral trade data and the abundance of zero trade flows. Thus, the model is given as follows in Equation (4):

$$CO_{2ijt} = \exp(\alpha_1 nat_ress_{it} \times int_{ijt} + \alpha_2 \sum_{k=1}^3 ECI_{ikt} \times int_{ijt} + \alpha_3 WTO_{ijt} + \alpha_4 RTA_{ijt} + \alpha_5 CU_{ijt} + \mu_{it} + \delta_{jt} + \pi_{ij}) \times \varepsilon_{ijt} \quad (4)$$

Where CO_{2ijt} is the volume of carbon incorporated in exports. When $i = j$, CO_{2ijt} represents national and international flows if $i \neq j$. The inclusion of domestic flows allows us to estimate the effect of international borders (Anderson et al., 2018b), domestic trade costs (Anderson, 2018a).

Including export-time fixed effects (μ_{it}) and importer-time fixed effects (δ_{jt}) in the estimation helps control for multilateral resistance terms. Baldwin and Taglioni (2006) highlight the difficulty of effectively capturing multilateral resistance and the potential for biased results, hence the recommendation to use country-time fixed effects. Furthermore, we incorporate pairwise fixed effects into the model to capture time-invariant bilateral relationships such as distance, a shared language, a common colonial past, and a shared religion. This also helps avoid the endogeneity bias of trade policy variables (Baier and Bergstrand, 2007).

The variable of interest in this study is given by [the variable], nat_ress_{it} which measures the share of natural resources in GDP. However, in the presence of fixed time-export effects that absorb all temporal variations of exporter-specific variables, it becomes impossible to estimate the effect of all time-varying exporter-related variables, including the variable of interest. In other words, a collinearity problem arises.

To overcome this limitation, we adopt the method of Heid et al. (2021) and Beverelli (2023), which first combines domestic and international flows for the dependent variable. Second, we interact these assumed collinear variables with a dyadic variable int_{ijt} that takes the value 1 when the dependent $i \neq j$ variable is active and 0 otherwise. This interaction allows us to quantify the impact of natural resources on international carbon flows relative to domestic flows. It also resolves endogeneity issues between carbon volumes in exports and natural resources.

The model also incorporates the diversification and sophistication of economies' productive capacities based on the economic complexity index (ECI_{it}). Stojkoski et al. (2023) distinguish three dimensions of economic complexity: (i) trade complexity; (ii) technology complexity; (iii) research economic complexity .

Trade agreements are represented by the binary variables WTO_{ijt} and RTA_{ijt} . They respectively represent the simultaneous membership of the exporter and importer in the World Trade Organization and a Regional Trade Agreement. CU_{ijt} is a dummy variable that measures the effect of a common currency on carbon transfer.

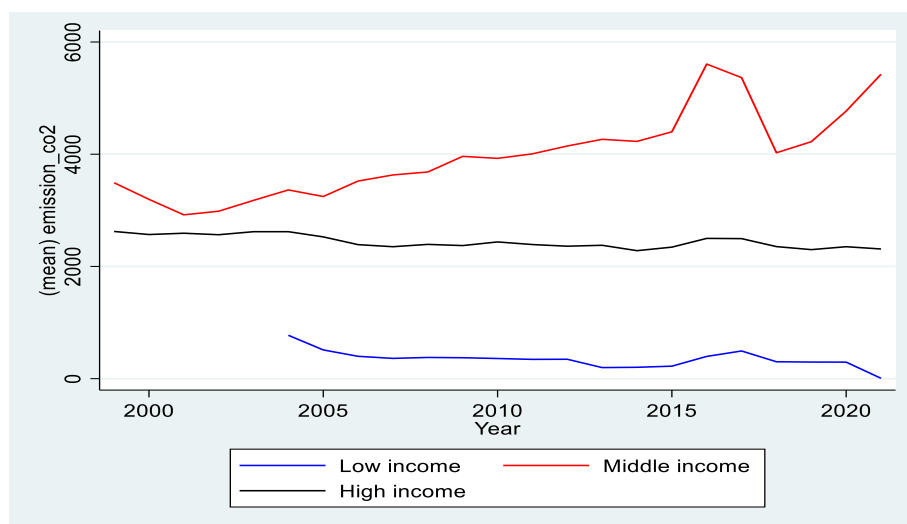
4. Data

4.1 Data on carbon emissions embodied in exports

This analysis is based on a sample of 106 exporting countries and 114 importing countries (see Table A.1 in the appendix for the countries included in the sample) whose data cover the period 1999-2021. Descriptive statistics are presented in Table A.2 in the appendix.

The data on carbon emissions in trade are obtained from the EORA database (. They report on carbon flows embodied by country pair. This measure has been used in recent work such as Wang et al. (2025). As shown in Figure 1, carbon emissions are trending according to the income level of economies. Middle-income countries have higher levels of carbon emissions and are experiencing an upward trend compared to high- and low-income countries. This can be explained by the high carbon intensity of the industrialization process. In high-income countries, the trend is stable but with a slight downward trend over the period. This could indicate a transition towards the production of green technologies using renewable energy.

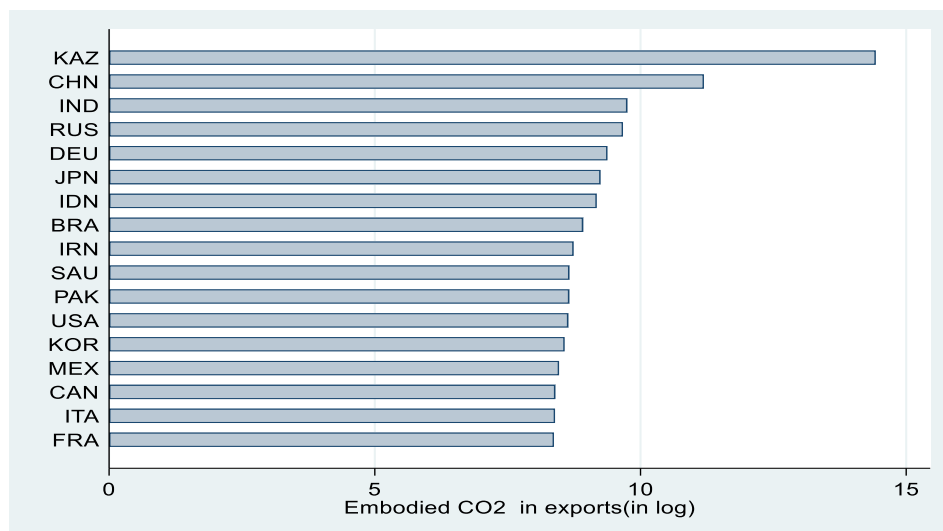
CO2 fluxes by volume incorporated in trade



Source: Authors

Furthermore, a detailed analysis (graph) shows that Kazakhstan has the largest carbon footprint in its exports, followed by China and India. These countries play a major role in the production and export of manufactured goods and use non-renewable energy in their industries, contributing to higher CO2 emissions.

Figure 2: Countries with the largest volumes of CO2 in exports

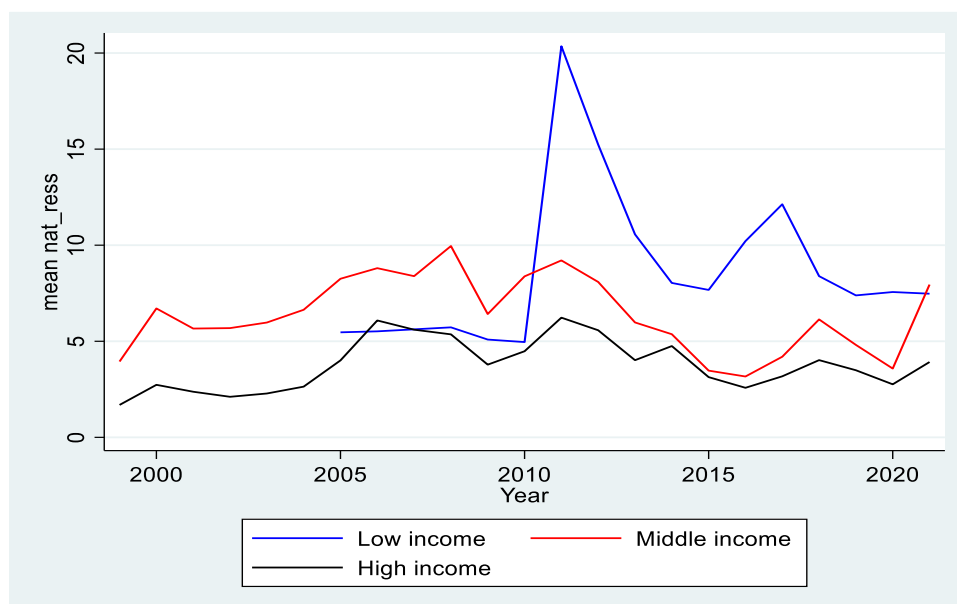


Source: Authors

4.2. Natural resource data

The data concerning natural resources come from the World Bank. This variable is widely used in the literature (Alemu, 2025; Chau et al., 2023). The graphs show the evolution of natural resource exploitation according to countries' income levels. Figure 3 **highlights** the dependence and sensitivity of low-income countries to natural resource shocks (Figure 4a).

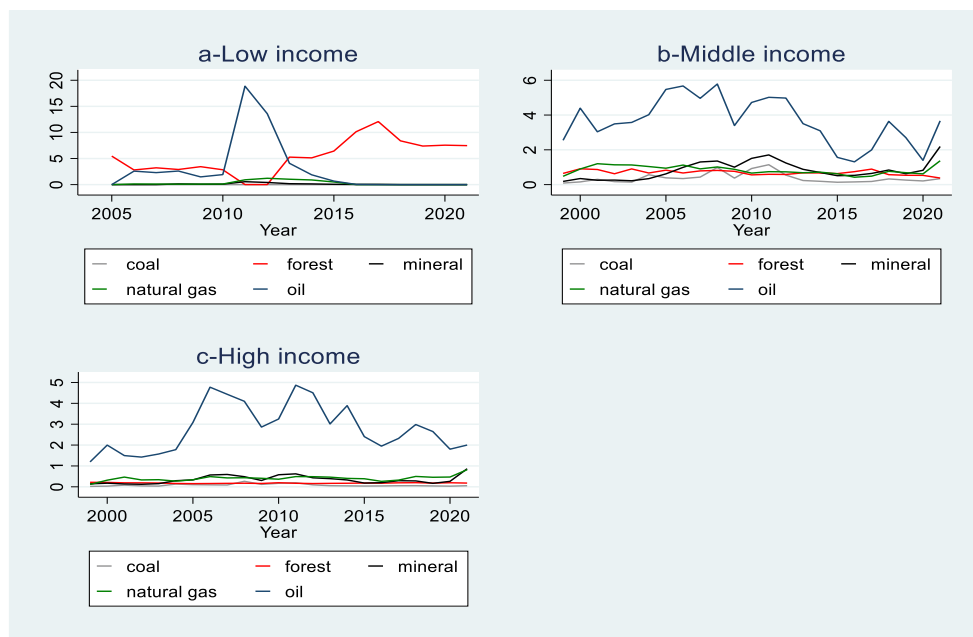
Figure 3: Evolution of the share of human resources in GDP



Sources: Authors

In contrast, middle- and high-income countries show a more or less stable trend. Furthermore, oil appears to be the natural resource that contributes most to GDP regardless of income level (Figure 4).

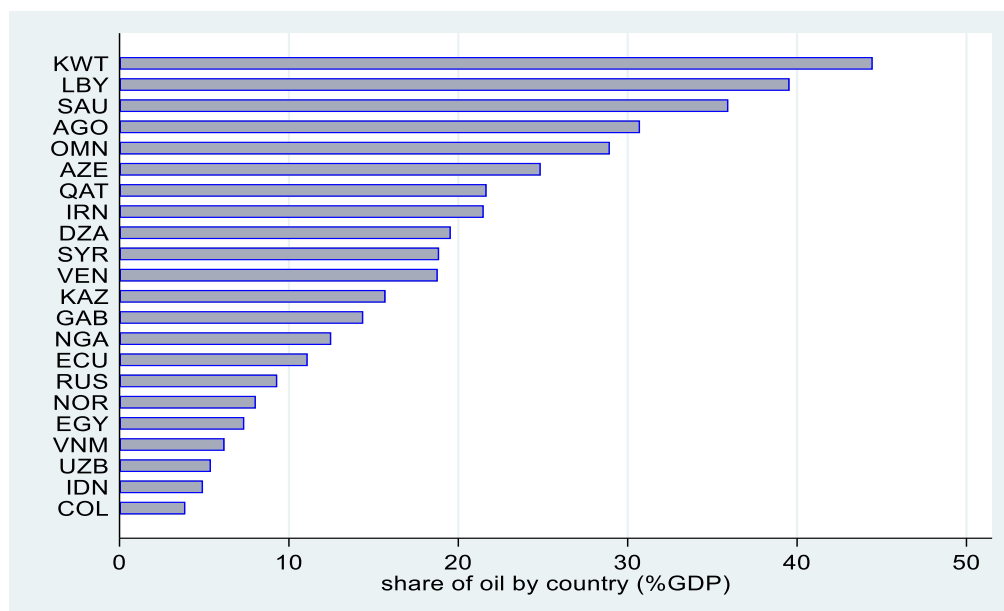
Figure 4: Evolution of natural resources



Source: Authors

Countries like Kuwait and Saudi Arabia (Figure 4.b) rely heavily on oil revenues, which on average represent more than 30% of GDP and finance the economy. Thus, the intensification of natural resource exploitation justifies the main objective of this study, which aims to determine the impact of these resources on carbon transfer in exports.

Figure 5: Oil-dependent countries



Sources: Authors

4.4. Other variables

The variable that measures economic complexity is an index comprising three dimensions developed by Stojkoski et al. (2023) and derived from the ECO (Economic Complexity Observatory). The first dimension concerns trade complexity and measures a country's capacity to produce and export sophisticated goods. The second focuses on technological complexity, reflecting an economy's ability to produce advanced technological innovations. Research complexity, which constitutes the third dimension, measures the level of sophistication of academic research in a country. In other words, it provides information on the impact of scientific publications, through the production of new knowledge, on production capacity and international competitiveness.

To take into account the effect of trade agreements (such as WTO_{ijt} ,) on RTA_{ijt} CO₂ emissions embodied in trade, CEPII (**Center for Prospective Studies and International Information.**) data are used. The presence of variables relating to trade in the gravity models makes it possible to capture trade frictions (Letlala and Johnson, 2025).

Regarding the impact of a monetary union, we construct a dyadic variable that takes the value 1 when the two countries share a common currency or belong to the same monetary union in period t . This variable allows us to understand the mechanism by which monetary integration affects carbon transfer in trade.

5. Results and discussions

The results of Equation (4) from the PPMLHDFE estimator are presented in Table 1. In column (1), we estimate only the effect of the variable of interest in Equation (4) taking into account the country and pair fixed effects.

Columns (2) to (6) progressively incorporate control variables. The results show that, regardless of the specification used, there is a statistically significant and positive relationship between natural resource exploitation and carbon emissions embodied in exports.

Furthermore, this result suggests that for each unit of natural resource exploited, there is a proportional increase in carbon emissions, thus justifying the presence of carbon in exported products. Indeed, Dong et al. (2017) show that products manufactured from natural resource exploitation contain carbon linked to the production process, which is subsequently exported. In other words, the carbon footprint resulting from the production of a good is also transferred to the destination country. Similarly, Wang et al. (2023) demonstrate that nickel mining, coupled with increasing demand, increases the carbon flows embedded in nickel products.

Furthermore, considering the disaggregated nature of natural resources (Table 2) confirms the positive relationship between different natural resources and the carbon embodied in exports. However, it can be observed that oil (column 5) has the greatest impact. The extraction, refining, transport, and consumption stages emit carbon that is transferred into petroleum products, thereby increasing embodied carbon flows in international trade.

Regarding the other exogenous variables, we observed that all three dimensions of economic complexity increase embodied carbon emissions. Despite the limited literature on the link between economic complexity and carbon emissions (Safi et al., 2023; You et al., 2022), our results align with those of Rafique et al. (2022), who demonstrate that economic complexity increases the carbon footprint. However, they diverge from those of Romero and Gramkow (2021).

Table 1. Baseline results

VARIABLES	Dependent variable: Embodied CO2						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>nat_ress_{it}</i>	0.0134*** (0.00198)	0.0269*** (0.00207)	0.0270*** (0.00202)	0.0242*** (0.00175)	0.0242*** (0.00174)	0.0228*** (0.00177)	0.0228*** (0.00177)
<i>ECI_trade_{it}</i>		0.646*** (0.0410)	0.616*** (0.0420)	0.633*** (0.0407)	0.631*** (0.0406)	0.659*** (0.0442)	0.659*** (0.0443)
<i>ECI_tech_{it}</i>			0.144*** (0.0267)	0.0947*** (0.0283)	0.0938*** (0.0282)	0.106*** (0.0301)	0.106*** (0.0301)
<i>ECI_research_{it}</i>				0.0805*** (0.0153)	0.0805*** (0.0153)	0.0523*** (0.0166)	0.0523*** (0.0166)
<i>WTO_{ijt}</i>					0.00728** (0.00344)	0.107*** (0.0264)	0.107*** (0.0264)
<i>RTA_{ijt}</i>						-0.0333 (0.0231)	-0.0334 (0.0231)
<i>CU_{ijt}</i>							-0.0757* (0.0408)
Constant	12.91*** (0.00201)	12.80*** (0.00682)	12.79*** (0.00761)	12.79*** (0.00749)	12.79*** (0.00829)	12.84*** (0.0273)	12.85*** (0.0277)
Observations	240,248	235,592	235,592	233,784	233,784	208,437	208,437
μ_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes
μ_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes
π_{ij}	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes : The variables are *nat_ress_{it}* for natural resource; *ECI_trade_{it}* for trade economic complexity, *ECI_tech_{it}* for technological economic complexity; *ECI_research_{it}* for research economic complexity; *WTO_{ijt}* for membership of *i* and *j* in the WTO; *RTA_{ijt}* for the regional trade agreements between *i* and *j*; *CU_{ijt}* for currency union between *i* and *j*; μ_{it} , μ_{it} and π_{ij} represent exporter-time, importer-time, and pair fixed effects respectively, ***p<0.01, **p<0.05, *p<0.1

Source: Authors

The coefficient associated with WTO membership is statistically significant. This indicates that increased global trade integration leads to more intense trade between countries and an increase in their embodied carbon emissions (Zhang and Li, 2024). Contrary to the findings of Zhang et al. (2022), regional trade agreements have no significant effect. Furthermore, a negative relationship is observed with sharing a common currency.

Table 2: Decomposition of the effect of natural resources

VARIABLES	Dependent variable: Embodied CO2				
	(1)	(2)	(3)	(4)	(5)
<i>coal_{it}</i>	0.0651*** (0.00631)				0.0328*** (0.00658)
<i>oil_{it}</i>		2.474*** (0.230)			2.149*** (0.236)
<i>mineral_{it}</i>			0.0435*** (0.00401)		0.0279*** (0.00343)
<i>forest_{it}</i>				0.137*** (0.0364)	0.128*** (0.0366)
<i>ECI_trade_{it}</i>	0.631*** (0.0441)	0.644*** (0.0449)	0.618*** (0.0445)	0.633*** (0.0464)	0.680*** (0.0451)
<i>ECI_tech_{it}</i>	0.0428 (0.0340)	0.139*** (0.0302)	0.0678** (0.0337)	0.0956*** (0.0346)	0.105*** (0.0303)
<i>ECI_research_{it}</i>	0.0609*** (0.0175)	0.0618*** (0.0166)	0.0664*** (0.0180)	0.0730*** (0.0182)	0.0432*** (0.0164)
<i>WTO_{ijt}</i>	0.100*** (0.0262)	0.101*** (0.0264)	0.0952*** (0.0258)	0.0964*** (0.0260)	0.102*** (0.0265)
<i>RTA_{ijt}</i>	-0.0277 (0.0239)	-0.0310 (0.0234)	-0.0324 (0.0236)	-0.0238 (0.0241)	-0.0324 (0.0232)
<i>CU_{ijt}</i>	-0.0756* (0.0414)	-0.0836** (0.0417)	-0.0718* (0.0402)	-0.0746* (0.0399)	-0.0824* (0.0427)
Constant	12.88*** (0.0270)	12.86*** (0.0277)	12.89*** (0.0268)	12.88*** (0.0278)	12.85*** (0.0283)
Observations	208,252	207,303	208,437	208,437	207,118
μ_{it}	Yes	Yes	Yes	Yes	Yes
μ_{it}	Yes	Yes	Yes	Yes	Yes
π_{ij}	Yes	Yes	Yes	Yes	Yes

Note : The variables *coal_{it}* for coal resource rents, *oil_{it}* for oil resource rents, *mineral_{it}* for mineral resources rent, *forest_{it}* for forest resources rent *ECI_trade_{it}* for trade economic complexity, *ECI_tech_{it}* for technological economic complexity; *ECI_research_{it}* for research economic complexity; *WTO_{ijt}* for membership of *i* and *j* in the WTO; *RTA_{ijt}* for the regional trade agreements between *i* and *j*; *CU_{ijt}* for currency union between *i* and *j*; μ_{it} , μ_{it} and π_{ij} represent exporter-time, importer-time, and pair fixed effects respectively, ***p<0.01, **p<0.05, *p<0.1

Source: Authors

6. Further investigations

6.1 Control of heterogeneity

We suspect that the link between natural resources and carbon embodied in exports is not uniform. To address this, we control for heterogeneity by accounting for income level. Table 3 shows that income level influences the effect of embodied carbon flows. In low-income economies, natural resources reduce carbon emissions. The exploitation of natural resources and the production of goods from them require the availability of significant technological resources, which low-income countries lack. In middle- and high-income economies, the impact is generally positive.

Table 3: Controlling for income level heterogeneity

VARIABLES	Dependent variable: Embodied CO2		
	LIC	MIC	HIC
<i>nat_ress_{it}</i>	-0.176*** (0.0399)	0.0229*** (0.00192)	0.0262*** (0.00171)
<i>ECI_trade_{it}</i>	0.608*** (0.0176)	0.649*** (0.0173)	0.620*** (0.0174)
<i>ECI_tech_{it}</i>	0.0874*** (0.0139)	0.0640*** (0.0139)	0.136*** (0.0139)
<i>ECI_research_{it}</i>	0.0778*** (0.00871)	0.0635*** (0.00874)	0.0650*** (0.00855)
<i>WTO_{ijt}</i>	0.0962*** (0.0142)	0.0950*** (0.0142)	0.109*** (0.0144)
<i>RTA_{ijt}</i>	-0.0264*** (0.00895)	-0.0244*** (0.00873)	-0.0367*** (0.00875)
<i>CU_{ijt}</i>	-0.0745*** (0.0184)	-0.0721*** (0.0185)	-0.0786*** (0.0187)
Constant	12.89*** (0.0139)	12.88*** (0.0140)	12.86*** (0.0144)
Observations	208,437	208,437	208,437
μ_{it}	Yes	Yes	Yes
μ_{it}	Yes	Yes	Yes
π_{ij}	Yes	Yes	Yes

Notes : The variables are *nat_ress_{it}* for natural resource; *ECI_trade_{it}* for trade economic complexity, *ECI_tech_{it}* for technological economic complexity; *ECI_research_{it}* for research economic complexity; *WTO_{ijt}* for membership of *i* and *j* in the WTO; *RTA_{ijt}* for the regional trade agreements between *i* and *j*; *CU_{ijt}* for currency union between *i* and *j*; μ_{it} , μ_{it} and π_{ij} represent exporter-time, importer-time, and pair fixed effects respectively, ***p<0.01, **p<0.05, *p<0.1

Source: Authors

6.2. Control of short- and long-term effects

Following Anderson and Yotov (2022), we estimate the short- and long-term effects. This estimation allows us to control for and absorb all factors that could influence carbon emissions having the same even-time dimension. It also mitigates the endogeneity linked to bilateral trade policies (Baier and Bergstrand, 2007). The model to be estimated is as follows in Equation (5):

$$CO_{2ijt} = \exp(\alpha_1 nat_ress_{it} \times int_{ijt} + \alpha_{2k} \sum_{k=1}^3 ECI_{ikt} \times int_{ijt} + \alpha_3 WTO_{ijt} + \alpha_4 RTA_{ijt} + \alpha_5 CU_{ijt} + \mu_{it} + \delta_{jt} + \pi_{ij} \Delta_t) \times \varepsilon_{ijt} (5)$$

With $\pi_{ij} \Delta_t$ fixed effects in pairs per time interval.

The results are presented in Table 4. Column 1 is an estimate of Equation (5) whose pairwise fixed effects vary with intervals of 3 years; column 2 is obtained with intervals of 6 years by pairwise fixed effects; columns 3 and 4 are obtained with intervals of 9 and 18 years respectively.

Two main findings emerge from Table 4. First, for each time interval, the results remain robust, with a positive and significant effect. Second, the effect gradually increases from the short term (column 1) to the long term (column 4). Thus, long-term exploitation of natural resources tends to increase carbon emissions more significantly.

Table 4: Short and long run

VARIABLES	Dependent variable: Embodied CO2			
	3 years	6_years	9_years	18_years
<i>nat_ress_{it}</i>	0.0136*** (0.00105)	0.0165*** (0.00146)	0.0175*** (0.00147)	0.0196*** (0.00145)
<i>ECI_trade_{it}</i>	0.450*** (0.0311)	0.397*** (0.0322)	0.643*** (0.0263)	0.641*** (0.0184)
<i>ECI_tech_{it}</i>	0.0508*** (0.0116)	0.110*** (0.0133)	0.151*** (0.0134)	0.159*** (0.0146)
<i>ECI_research_{it}</i>	0.0759*** (0.0125)	-0.0149* (0.00866)	0.0132 (0.0101)	0.0783*** (0.00831)
<i>WTO_{ijt}</i>	-0.00321 (0.0232)	0.0449** (0.0200)	0.0577*** (0.0166)	0.0583*** (0.0166)
<i>RTA_{ijt}</i>	-0.0244** (0.00998)	-0.0277** (0.0118)	-0.00612 (0.0112)	0.00788 (0.00831)
<i>CU_{ijt}</i>	0.000956 (0.0146)	0.00609 (0.0158)	0.0158 (0.0259)	0.0188 (0.0192)
Constant	13.01*** (0.0214)	12.96*** (0.0183)	12.89*** (0.0158)	12.88*** (0.0163)
Observations	204,722	207,301	207,869	208,282
μ_{it}	Yes	Yes	Yes	Yes
μ_{it}	Yes	Yes	Yes	Yes
π_{ij}	Yes	Yes	Yes	Yes

Notes : The variables are *nat_ress_{it}* for natural resource; *ECI_trade_{it}* for trade economic complexity, *ECI_tech_{it}* for technological economic complexity; *ECI_research_{it}* for research economic complexity; *WTO_{ijt}* for membership of *i* and *j* in the WTO; *RTA_{ijt}* for the regional trade agreements between *i* and *j*; *CU_{ijt}* for currency union between *i* and *j*; μ_{it} , μ_{it} and π_{ij} represent exporter-time, importer-time, and interval year pair fixed effects respectively, ***p<0.01, **p<0.05, *p<0.1

Source: Authors

6.3. Control of the intensity of natural resource exploitation

The APPML estimator developed by Bergstrand et al. (2025) is used to control for skewed effects across the entire distribution. This method is based on expectiles and allows the effect of natural resources to be decomposed according to the level of distribution of the dependent variable. Although the positive effect is robust, the results show that as resource exploitation intensifies, the effect diminishes. Furthermore, Figure 6 confirms the diminishing effect as the time period increases, with a steeper negative slope over longer periods.

Table 5 : APPML estimator

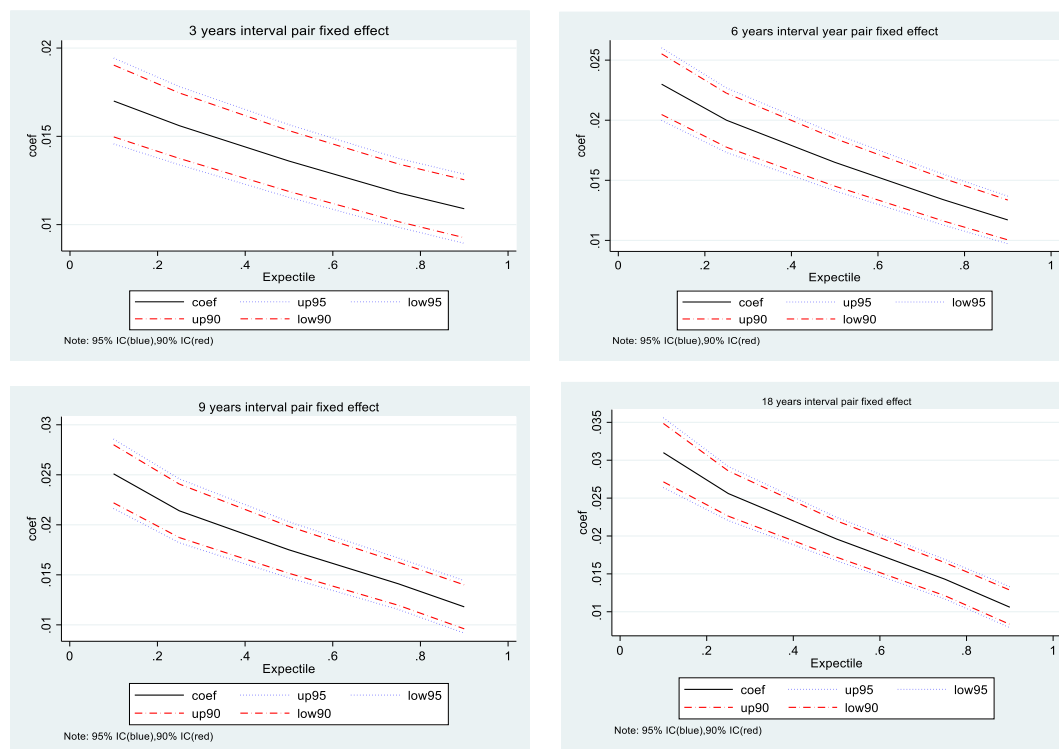
VARIABLES	Dependent variable: Embodied CO2				
	0.10	0.25	0.50	0.70	0.90
<i>nat_ress_{it}</i>	0.0319*** (0.00139)	0.0281*** (0.00134)	0.0228*** (0.00131)	0.0187*** (0.00126)	0.0138*** (0.00123)
<i>ECI_trade_{it}</i>	0.771*** (0.0196)	0.719*** (0.0175)	0.659*** (0.0170)	0.612*** (0.0172)	0.547*** (0.0179)
<i>ECI_tech_{it}</i>	0.141*** (0.0164)	0.122*** (0.0144)	0.106*** (0.0133)	0.0970*** (0.0131)	0.0847*** (0.0149)
<i>ECI_research_{it}</i>	0.0651*** (0.0110)	0.0620*** (0.00965)	0.0523*** (0.00865)	0.0424*** (0.00816)	0.0286*** (0.00849)
<i>WTO_{ijt}</i>	0.0956*** (0.0135)	0.105*** (0.0143)	0.107*** (0.0144)	0.0974*** (0.0147)	0.0765*** (0.0148)
<i>RTA_{ijt}</i>	-0.0405*** (0.0110)	-0.0383*** (0.00976)	-0.0334*** (0.00853)	-0.0283*** (0.00797)	-0.0173*** (0.00739)
<i>CU_{ijt}</i>	-0.0182 (0.0147)	-0.0412** (0.0169)	-0.0757*** (0.0187)	-0.0986*** (0.0198)	-0.117*** (0.0213)
Constant	13.44*** (0.0134)	13.11*** (0.0141)	12.85*** (0.0145)	12.80*** (0.0149)	13.02*** (0.0154)
Observations	208,437	208,437	208,437	208,437	208,437
μ_{it}	Yes	Yes	Yes	Yes	Yes
μ_{it}	Yes	Yes	Yes	Yes	Yes
π_{ij}	Yes	Yes	Yes	Yes	Yes

Notes : The variables are *nat_ress_{it}* for natural resource; *ECI_trade_{it}* for trade economic complexity, *ECI_tech_{it}* for technological economic complexity; *ECI_research_{it}* for research economic complexity; *WTO_{ijt}* for membership of *i* and *j* in the WTO; *RTA_{ijt}* for the regional trade agreements between *i* and *j*; *CU_{ijt}* for currency union between *i* and *j*; μ_{it} , μ_{it} and π_{ij} represent exporter-time, importer-time, and pair fixed effects respectively, ***p<0.01, **p<0.05, *p<0.1

Source: Authors

Resource depletion could be a contributing factor. Indeed, the quantities of available resources decrease following the intensification of exploitation, thus limiting the long-term positive impact.

Graph 6: APPML short and long run



Source: Authors

6.4. Controlling for endogeneity

There is a potential endogeneity bias due to the omission of relevant variables. Indeed, factors not included in the model can influence both the dependent variable and exogenous variables, thus leading to biased results. For example, variables such as environmental policies can influence both natural resources and embodied carbon fluxes, but they are not included in the model, which introduces bias. Within the gravity model, the IV-PPML estimator is appropriate for controlling this endogeneity bias.

This estimator is recommended when explanatory variables are suspected of being endogenous. One of the difficulties in implementing this method is choosing valid instruments, which is crucial for the validity of the results (Lewbel, 2012). To this end, an instrument must satisfy three conditions: orthogonality; a strong correlation with the suspected endogenous variable; and exogeneity of the instrumental variable. However, it is difficult to find an instrument that satisfies all three conditions. Therefore, Lewbel (2012) recommends using internal instruments based on the lags or differences of the variables suspected of being endogenous.

In this paper, we use first differences between natural resources and economic complexity indices. Although the effect is smaller, it nevertheless confirms the robustness of the positive impact of natural resources on embodied carbon emissions.

Table 6: Controlling for endogeneity

VARIABLES	Dependent variable: Embodied CO2
	Additive
nat_ress_{it}	0.00835*** (0.00315)
ECI_trade_{it}	0.122* (0.0706)
ECI_tech_{it}	-0.0392* (0.0218)
$ECI_research_{it}$	-0.0152 (0.0405)
WTO_{ijt}	2.525*** (0.0833)
RTA_{ijt}	-1.128*** (0.0734)
CU_{ijt}	0.135 (0.116)
Constant	5.787*** (0.0569)
Observations	207,087
Settings	8
Moments	8
Fixed effect	No

Notes : The variables are nat_ress_{it} for natural resource; ECI_trade_{it} for trade economic complexity; ECI_tech_{it} for technological economic complexity; $ECI_research_{it}$ for research economic complexity; WTO_{ijt} for membership of i and j in the WTO; RTA_{ijt} for the regional trade agreements between i and j ; CU_{ijt} for currency union between i and j ; μ_{it} , μ_{it} and π_{ij} represent exporter-time, importer-time, and pair fixed effects respectively, ***p<0.01, **p<0.05, *p<0.1

Source: Authors

7. Conclusion and implications

7.1. Conclusion

Using embodied carbon data from the EORA database, we constructed a gravity model adapted to carbon transfer for 106 exporting and 114 importing countries for the period 1999–2021. We analyzed the impact of natural resources on carbon transfer in trade. The main results are as follows:

The exploitation of natural resources leads to an increase in carbon emissions related to exported goods. Countries with natural resources where extraction, production, and export promote carbon transfer are particularly affected. Furthermore, this impact varies considerably among different categories of natural resources. However, oil is the resource that contributes most to carbon transfer in trade. Income level also influences the amount of carbon absorbed. Indeed, the effect is more moderate in low-income countries compared to middle- and high-income economies where the impact is more pronounced.

7.2. Theoretical Implications

The results obtained make theoretical contributions at several levels and offer a better understanding of the determinants of carbon transfers. The positive effect of natural resources on carbon transfer shows that economies heavily dependent on the exploitation of natural resources tend to specialize in polluting industries, thus producing goods with a high carbon footprint. The same is true for the different dimensions of economic complexity. This finding confirms, within the theory of international trade, the hypothesis of economic specialization in sectors where they have a comparative advantage, to the detriment of the environment.

Similarly, global trade liberalization, characterized by WTO membership, promotes carbon transfer embedded in traded goods. Conversely, at the regional level, green specialization reduces carbon emissions.

In the theory of optimal currency areas, sharing a common currency promotes increased trade and contributes to economic stability. The idea that monetary union could reduce carbon emissions embodied in exports introduces a new dimension: environmental externalities. In other words, beyond traditional advantages such as reduced transaction costs and exchange rate risk, sharing a common currency could also mitigate the negative environmental impacts of trade.

7.3. Practical and political implications

Managing carbon emissions is emerging as a key factor in economic competitiveness. Economies must reorient their industrialization strategies by investing in green technologies such as renewable energies, low-carbon manufacturing processes. These investments stimulate innovation, create skilled jobs, and strengthen long-term economic resilience. Governments

must also encourage the energy transition by providing incentives for the adoption of clean energy, carbon pricing mechanisms, and subsidies for sustainable production practices, in order to reduce the carbon intensity of domestic industries and promote the energy transition.

Trade liberalization, while essential for economic growth, should not come at the expense of the environment. Policymakers must ensure that trade agreements include environmental clauses, encourage the transfer of green technologies, and set standards for low-carbon products. For instance, environmental clauses in free trade agreements can incentivize exporters to adopt sustainable production methods and implement mechanisms for monitoring and reporting carbon emissions associated with traded goods.

International cooperation is also crucial. Multilateral initiatives, such as common carbon accounting systems, cross-border carbon pricing, and collaboration on low-carbon innovation, can enhance the effectiveness of national policies and prevent carbon leakage. By aligning industrial, trade, and regulatory policies, governments can simultaneously promote economic growth, industrial competitiveness, and environmental sustainability.

7.4. Limits and future directions

The shortcomings identified in this paper suggest the possibility of further research. To this end, the study does not utilize other measures of carbon emissions embodied in exports from other databases, which could affect the robustness of the results. Sectoral heterogeneity is also not taken into account. Some sectors may have a larger carbon footprint than others, which can influence carbon transfer levels.

These limitations open the way to several avenues of future research, including comparing the results with other data sources, integrating sectoral heterogeneities, and the impact of environmental policies.

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Appendix

Table A1

List exporting countries					
Albania	Chile	Greece	Lithuania	Portugal	Tunisia
Algeria	China	Guatemala	Madagascar	Qatar	Turkey
Angola	Colombia	Hong Kong	Malaysia	Romania	UK
Argentina	Costa Rica	Hungary	Mexico	Russia	USA
Armenia	Cote dlvoire	India	Moldova	Saudi Arabia	Uganda
Australia	Croatia	Indonesia	Mongolia	Senegal	Ukraine
Austria	Cuba	Iran	Morocco	Serbia	Uruguay
Azerbaijan	Czech Republic	Ireland	Namibia	Singapore	Uzbekistan
Bangladesh	Denmark	Israel	Netherlands	Slovakia	Venezuela
Belarus	Dominican Republic	Italy	New Zealand	Slovenia	Viet Nam
Belgium	Ecuador	Jamaica	Nigeria	South Africa	Zimbabwe
Bolivia	Egypt	Japan	North Korea	South Korea	
Bosnia and Herzegovina	El Salvador	Jordan	Norway	Spain	
Botswana	Finland	Kazakhstan	Oman	Sri Lanka	
Brazil	France	Kenya	Pakistan	Sweden	
Bulgaria	Gabon	Kuwait	Panama	Switzerland	
Cambodia	Georgia	Laos	Peru	Syria	
Cameroon	Germany	Lebanon	Philippines	Tanzania	
Canada	Ghana	Libya	Poland	Thailand	

Source : Authors

Table A2 : Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
CO_{2ijt}	243646	3158.247	88577.031	0	13200000
nat_ress_{it}	240598	5.248	9.019	0	61.035
ECI_trade_{it}	238510	.389	.855	-1.841	2.229
ECI_tech_{it}	243646	.05	.998	-3.008	1.599
$ECI_research_{it}$	239847	.212	1.02	-3.108	2.859
WTO_{ijt}	243646	.686	.464	0	1
RTA_{ijt}	217756	.166	.372	0	1
CU_{ijt}	243646	.072	.259	0	1

Source: Authors

Table A3: Pairwise correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) CO_{2ijt}	1.000								
(2) nat_ress_{it}	-0.001	1.000							
(3) ECL_trade_{it}	0.010*	-	1.000						
		0.356*							
(4) ECL_tech_{it}	0.021*	-	0.761*	1.000					
		0.342*							
(5) $ECL_research_{it}$	-	-	0.544*	0.567*	1.000				
	0.007*	0.294*							
(6) WTO_{ijt}	0.013*	-	0.091*	0.110*	0.183*	1.000			
		0.159*							
(7) RTA_{ijt}	-	-	0.164*	0.152*	0.131*	0.119*	1.000		
	0.008*	0.098*							
(8) CU_{ijt}	0.008*	-	0.279*	0.258*	0.301*	0.069*	0.131*	1.000	
		0.156*							

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source : Authors