Unpacking France's Emissions Paradox: The Role of FDI

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Abstract

This paper examines the role of Foreign Direct Investment (FDI) in the decoupling of economic growth and emissions observed in France in recent decades. Despite increased production, domestic emissions have notably decreased, suggesting that offshoring through FDI may be a key driver of this paradox. Using sectoral FDI data over a 24-year period, we decompose France's CO2 emissions linked to FDI into scale, composition, and technique effects. Our main findings indicate that while the scale effect is substantial, it is partly offset by a composition effect, as FDI is increasingly directed towards regions with more lenient environmental regulations, such as Asia and Africa. In these regions, emissions are five and nine times higher, respectively, than the corresponding emissions from FDI directed towards France. Furthermore, we identify a technique effect, driven by the adoption of cleaner production technologies, which has contributed to a 40% reduction in French emissions. This effect has more than offset the scale effect, emerging as the primary explanation for the observed decline in emissions—well before the Paris Agreement came into force. Lastly, we demonstrate through a simple empirical model that environmental regulations significantly contribute to the materialization of these effects, underscoring the need for coordinated policies across countries to effectively address the climate crisis.

Keywords: Carbon Leakage, Composition Effect, Emissions Decoupling, Environmental Regulations, Foreign Direct Investment (FDI), Offshoring, Scale Effect, Technique Effect

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1 Introduction

The relationship between international trade, FDI, and carbon emissions is complex, particularly in the context of increasingly integrated global value chains (GVCs). As production processes become more fragmented across borders, GVCs can simultaneously foster economic efficiency and exacerbate environmental impacts. On the one hand, they facilitate the diffusion of green technologies, encouraging firms to adopt cleaner and more energy-efficient production methods and reduce their environmental footprint. On the other hand, the expansion of GVCs increases transportation-related emissions and may incentivize firms to relocate to regions with weaker environmental regulations, reinforcing the so-called Pollution Haven Effect (Copeland and Taylor, 2000). The paradoxical nature of these effects raises critical questions about how GVCs and FDI shape emissions dynamics, and understanding these interactions is crucial to fully grasp the environmental implications of economic integration.

France, a key player in Europe, offers a compelling case to examine the evolution of FDI and GVCs in relation to emissions dynamics. As one of the world's largest economies, with a GDP of approximately $3,030.90 billion in 2023, France ranks as the seventh largest economy worldwide. The country is deeply integrated into GVCs, with steadily increasing participation rates over recent decades. According to the OECD trade-in-value-added database, France's participation in GVC rose from 39.6% in 2000 to a peak of 49.3% in 2018, highlighting a growing economic interdependence. Since 2019, France has also emerged as the leading recipient of FDI in Europe (UNCTAD, 2024). France's involvement in GVC extends to both upstream and downstream activities. In 2021, the foreign value added to its exports reached approximately 21%, while the domestic value added embedded in foreign exports was approximately 25.5%. The significance of France's integration into GVCs is particularly evident across various sectors. For instance, the coke and refined petroleum sector exhibited an impressive 87% GVC participation rate, with most of its output directed towards foreign markets. Similarly, the mining and quarrying sector demonstrated strong GVC integration at 72.8%, with nearly half of its value sourced from abroad. Key manufacturing industries such as basic metals and transport equipment also maintain high GVC involvement, underscoring France's reliance on cross-border production networks.

Despite this growth in production and integration into GVCs, France has managed to reduce its domestic greenhouse gas (GHG) emissions significantly (see Figure 1). Between 1970 and 2022, GHG emissions fell by approximately 33%, presenting what some have termed an "emissions paradox" (Wiedenhofer et al., 2020; Haberl et al., 2020) given the sustained economic expansion.

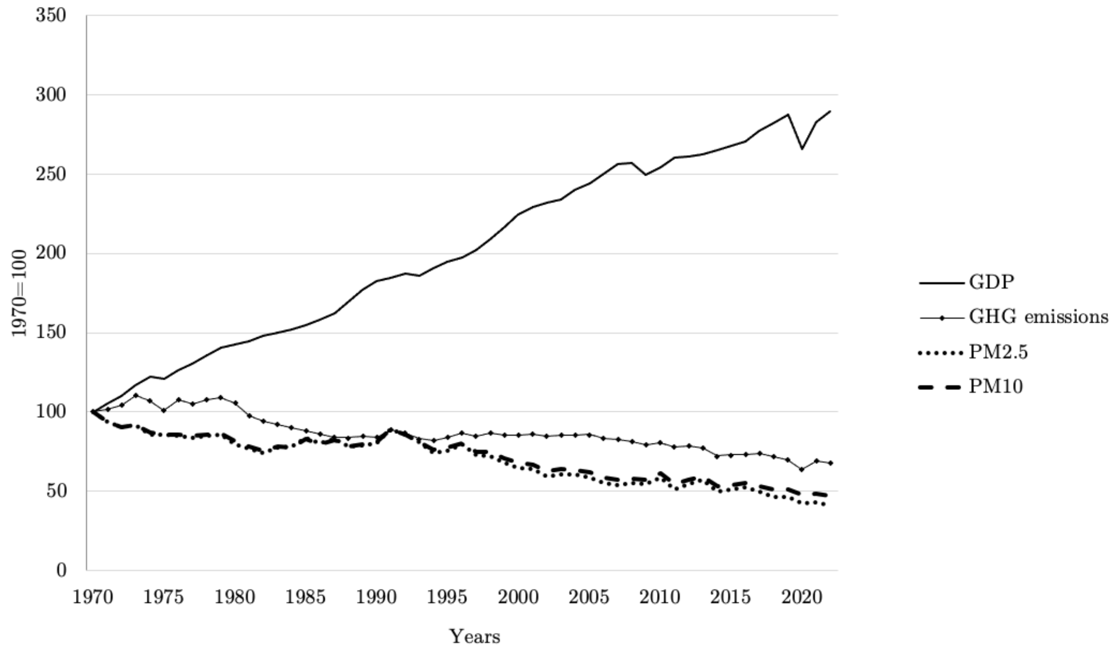


Figure 1: Breaking the Link Between Economic Growth and Emissions in France

These divergent paths challenge the traditional view that economic expansion inherently leads to higher emissions due to increased production. To dissect this phenomenon, scholars have examined the underlying mechanisms through which emissions trends decouple from economic growth. Central to this discussion are the scale, composition, and technique effects, initially conceptualized by Grossman and Krueger (1991) in their foundational work on the environmental implications of the North American Free Trade Agreement (NAFTA). First, the scale effect refers to the direct relationship between economic output and emissions, consistent with the traditional view, where an increase in production leads to higher emissions, unless offset by other factors. Second, the composition effect refers to changes in the industrial structure of an economy that can influence overall emissions. This effect occurs when the economic focus shifts from pollution-intensive to clean industries or when the former relocate to countries with less stringent environmental regulations (Copeland and Taylor, 2000). Lastly, the technique effect represents improvements in production processes that reduce emissions per unit of output. This effect emerges through technological advancements, often driven by regulatory pressure and market competition. The technique effect is closely related to the Porter Hypothesis (Porter and van der Linde, 1995), which argues that stringent environmental regulations can promote innovation and the development of environmentally friendly technologies, benefiting both the economy and the environment.

Building on these concepts, this paper aims to explore the dynamics underlying France's emissions paradox to assess the extent to which FDI provides an explanation. Our objective is to discern whether the observed reduction in GHG emissions genuinely reflects a sustainable transition or is merely an artifact of shifting pollution-intensive activities abroad through FDI. By examining the interplay of scale, composition, and technique effects within the context of France's integration into GVCs and its FDI patterns, we seek to provide a comprehensive understanding of the factors driving this paradox.

To achieve this goal, we draw on the methodological framework established by Levinson (2023), who investigates pollution embodied in trade to explore whether high-income countries are reducing domestic pollution or simply outsourcing it. Levinson's approach involves a multi-step accounting exercise to calculate pollution intensity for each product, enabling the estimation of pollution displacement linked to imports. By quantifying how much pollution would have been generated had these products been manufactured domestically, he sheds some light on the complexities of carbon leakage in global trade. In our study, we adapt Levinson's methodology in several key ways. First, we focus specifically on outward FDI rather than imports to better isolate the offshoring effect. Second, we incorporate country-specific emissions data to more accurately capture the actual composition effect, moving beyond the assumption of uniform emissions intensity across all countries. This refinement underscores the composition effect, which Levinson's study dismissed as negligible, but this is ultimately an empirical question. Lastly, we analyze the contribution of the technique effect, which was not considered in Levinson's framework, as he assumes constant emissions intensity over time. By incorporating time-specific emissions data and comparing our results with those derived from Levinson's methodology, we isolate the technique effect, which emerges as twice as relevant as the composition effect in our findings.

The paper is organized as follows. Section 2 provides descriptive statistics and stylized facts on French FDI. In Section 3, we present our revised version of Levinson's carbon leakage indicator, adapting his approach to reflect the specific context of outward FDI. Section 4 outlined the findings of our research, while Section 5 concludes with some recommendations.

2 An Analysis of French FDI Dynamics

The globalization that took off in the late 20th century has significantly reshaped the global economic landscape. Liberalization of trade policies, coupled with advancements in transportation and communication technologies, have accelerated the movement of goods, services and capital across borders (Baldwin, 2016). While multilateral trade liberalization has played a key role in this process, regional integration has also gained momentum, driven by geographic and economic proximity (Krugman, 1991), formal agreements (Baldwin, 1997), and the domino effect (Baldwin, 1997), where economic interdependence and competitive pressures push external countries to seek entry into established trade blocs. As a result, major regional economic blocs have emerged, including the Southern Common Market (MERCOSUR), the Association of Southeast Asian Nations (ASEAN), and most notably, the European Union (EU). One of the most significant milestones in European integration was the establishment of the Schengen Area (1995), which eliminated internal border controls and facilitated economic exchanges across member states. This deeper integration has also accelerated the internationalization of production, fostering the expansion of GVCs within the EU. Companies increasingly fragment production across multiple countries, leveraging each member state's comparative advantages. This has led to greater specialization, with Germany excelling in high-tech manufacturing, Italy and Spain in textiles, and France in the aerospace and luxury goods industries.

In addition to these regional advantages, the search for further opportunities often takes firms beyond Europe, where other factors come into play. Non-EU markets, such as China and India, offer considerable advantages, not only in terms of labor costs but also due to regulatory environments that may be more flexible. These countries often have less stringent environmental regulations, which reduces the overall cost of production (Copeland and Taylor, 2000). FDI plays a critical role in this expansion, enabling firms to establish operations abroad or form strategic partnerships that deepen their global reach and enhance their competitive advantage in these emerging markets.

2.1 Trends in FDI Over Time

France, as a key player in the global economy, has not been exempt from these trends. The country has seen a significant increase in its involvement in both inbound and outbound FDI over the past few decades, as illustrated in Figure 2. From 1990 to 2023, outbound FDI increased by a factor of 13, while inbound FDI is now nine times larger than it was at the beginning of the period. French multinational firms have increasingly sought to expand their operations abroad, taking advantage of international markets and production opportunities. At the same time, France has become an attractive destination for foreign investment, benefiting from its central position within the European Union and its advanced industrial base. Even though the gap between outward and inward FDI has widened over time, it is not necessarily alarming, as France has maintained its position as the leading recipient of FDI in Europe since 2019, as confirmed by the 2023 report on trade and development (UNCTAD, 2024).

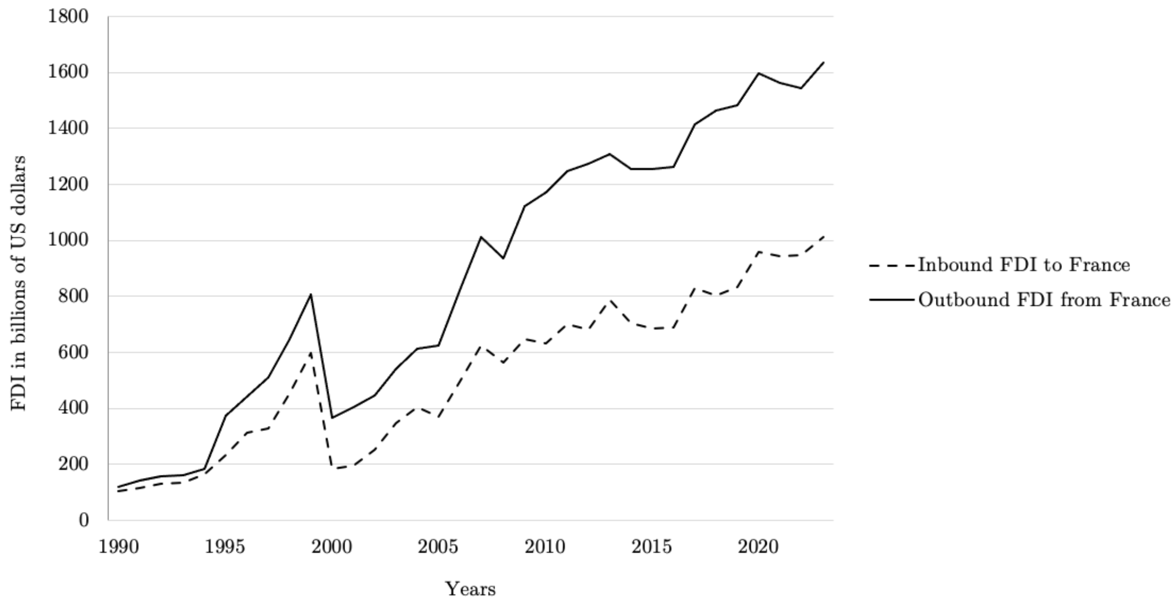


Figure 2: FDI stocks from and to France

2.2 FDI Top Sectors and Pollution Implications

When breaking down French FDI by sector for 2023, we observe that manufacturing remains the dominant sectors for both inward and outward FDI flows (see Fig.3). Within manufacturing, certain sectors stand out. Figure 4 highlights the most relevant industries, particularly those with significant environmental challenges. In the chemical industry, despite its substantial environmental impact, FDI inward and outward is relatively balanced. Meanwhile, the pharmaceutical sector stands out with a significant amount of outward FDI, reflecting France's expanding global influence in this innovative and research-driven field. The transport equipment industry, grappling with the challenges of ecological transition, also exhibits an excess of outward FDI compared to inward flows. This is likely due to the use of foreign inputs to remain competitive in the highly contested European market. Even the food sector, though less emissions-intensive than others, shows a clear surplus of outward FDI, highlighting the international expansion of French firms in this area. The dominance of these manufacturing sectors in French FDI is not new; France had already begun establishing its presence in these strategic industries globally after the end of the subprime crisis (see Appendix A1). The period after 2008 saw a substantial increase in outward FDI, driven by the rapid expansion of global value chains. This strategic internationalization was particularly pronounced in key sectors such as pharmaceuticals, chemicals, and automotive, as French firms sought to leverage new market opportunities and bolster their competitiveness.

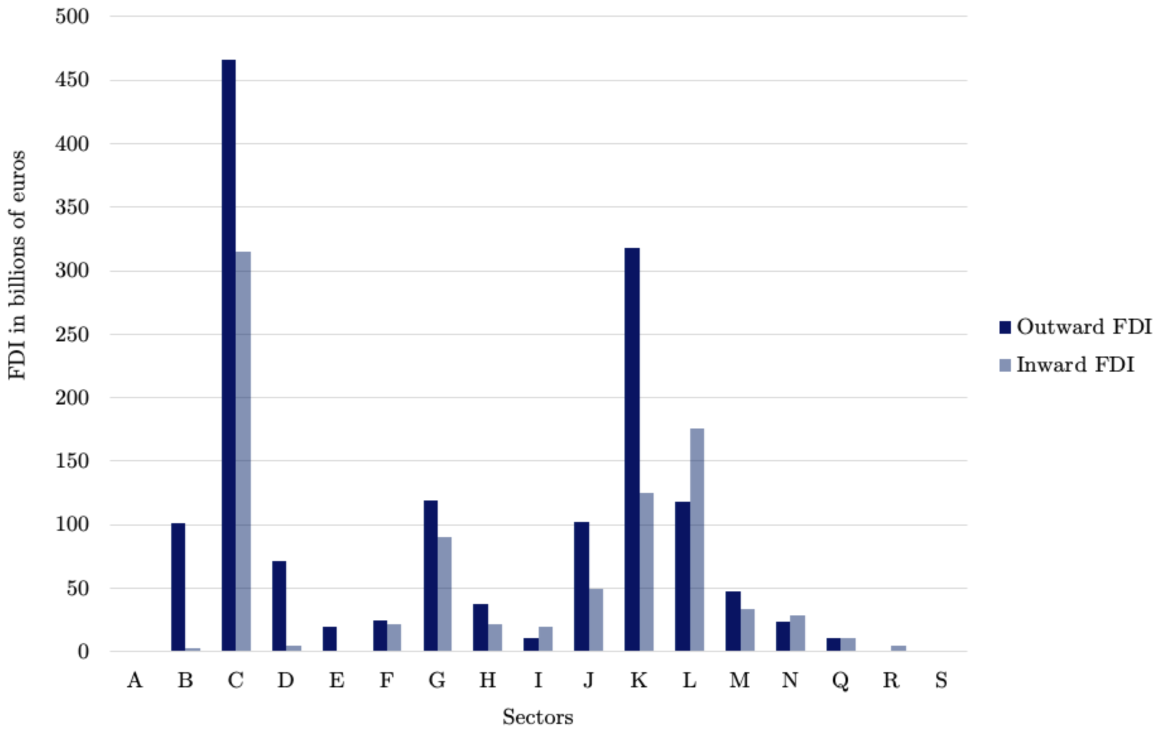


Figure 3: 2023 FDI inward and outward flows by sectors

Note : A - Agriculture, Forestry, and Fishing; B - Mining and Quarrying; C - Manufacturing; D - Electricity, Gas, Steam, and Air Conditioning Supply; E - Water Supply; Sewerage, Waste Management, and Remediation Activities; F - Construction; G - Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; H - Transportation and Storage; I - Accommodation and Food Service Activities; J - Information and Communication; K - Financial and Insurance Activities; L - Real Estate Activities; M - Professional, Scientific, and Technical Activities; N - Administrative and Support Service Activities; Q - Human Health and Social Work Activities; R - Arts, Entertainment, and Recreation; S - Other Service Activities.

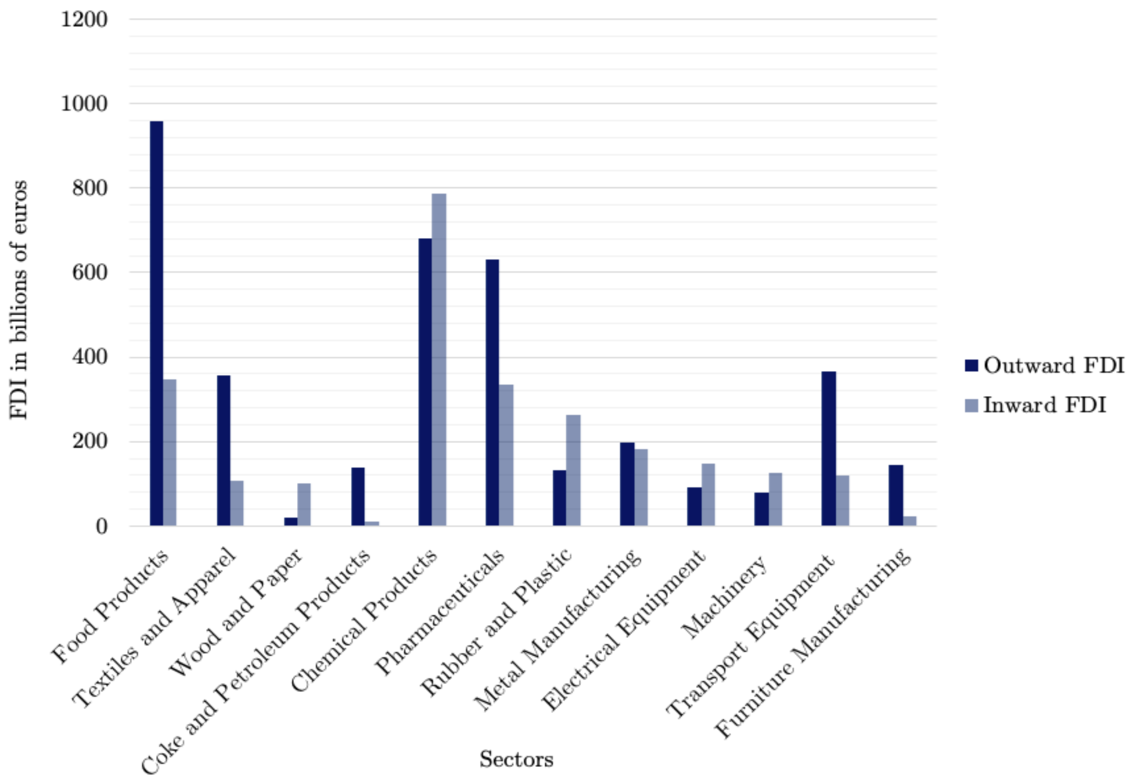


Figure 4: 2023 FDI inward and outward flows by manufacturing industries

When analyzing emissions data, the figures shown in Table 1 highlight a notable overlap between the most polluting and the most frequently relocated sectors. Specifically, among the top five polluting sectors, three (C10T12, C20 and C21) are also highly prone to relocation (see column (1) of Table 1). Analyzing changes in direct and indirect emissions share over the period from 2000 to 2015 provides valuable information on the environmental dynamics of these sectors. Throughout the period, the share of direct emissions, those produced within France, has steadily declined (see column (4) of Table 1), giving way to an increase in indirect emissions. For example, the share of direct emissions in sectors C13 and C14 decreased significantly from 36% to 9% (columns (2)-(3)). This decline implies a greater reliance on GVCs, as more emissions are now associated with imported inputs rather than domestic production. In addition, the pharmaceutical sector (C21), a pollution-intensive industry, experienced a decrease in its share of direct emissions by 21% over the period. These results may stem from France strategically shifting towards less polluting processes, such as assembly and research and development, while offshoring the more environmentally harmful aspects of production.

Table 1: French Emissions Data and Shares of Direct Emissions for 2000 and 2015

	(1)	(2)	(3)	(4)
Activity Code	Total Emissions per 1000 Units (2015)	Share of Direct Emissions (2000)	Share of Direct Emissions (2015)	Growth Rate
C10, C11, C12	3.075	10%	7%	-27%
C13, C14	1.824	36%	9%	-75%
C16, C17, C18	5.138	29%	25%	-14%
C19	1.735	50%	48%	-5%
C20	2.278	20%	22%	8%
C21	3.317	59%	47%	-21%
C22	3.768	59%	56%	-5%
C24, C25	1.664	13%	12%	-12%
C26	1.460	7%	4%	-36%
C28	1.189	19%	16%	-14%
C29	1.408	20%	13%	-34%
C30	1.680	7%	6%	-6%

Notes: CO2 emissions from De Melo and Solleder (2023) .

The activity codes correspond to the following classifications. C10, C11, C12 - Manufacture of Food Products, Beverages, and Tobacco Products; C13, C14 - Manufacture of Textiles and Wearing Apparel; C16, C17, C18 - Manufacture of Wood and Paper Products and Printing; C19 - Manufacture of Coke and Refined Petroleum Products; C20 - Manufacture of Chemicals and Chemical Products; C21 - Manufacture of Pharmaceuticals, Medicinal Chemical and Botanical Products; C22 - Manufacture of Rubber and Plastic Products; C24, C25 - Manufacture of Basic Metals and Fabricated Metal Products; C26 - Manufacture of Computer, Electronic, and Optical Products; C28 - Manufacture of Machinery and Equipment; C29 - Manufacture of Motor Vehicles, Trailers, and Semi-trailers; C30 - Manufacture of Other Transport Equipment.

2.3 Key Destinations of French FDI

French outward FDI exhibited a diverse geographical distribution in 2023, with significant flows directed toward both advanced and emerging markets, as shown in Figure 5. The Netherlands emerged as the largest recipient of French FDI, attracting an impressive 228,809 million euros, closely followed by the United States with 224,823 million euros. European destinations played a significant role, particularly the UK, Belgium, Germany, Spain, and Italy, alongside the Netherlands, highlighting the ongoing relevance of established markets within the continent. Beyond Europe, emerging economies are increasingly capturing French investments, particularly China, Brazil, and India, reflecting a strategic focus on high-growth regions. However, this shift towards emerging markets is a relatively recent phenomenon, as highlighted by the comparison between French outward FDI in 2000 and the top 25 recipient countries in 2023 shown in Figure 6. This transition towards emerging markets marks a significant evolution in French investment strategies, moving away from a primarily Euro-American focus. In Africa, countries such as Morocco, Angola and South Africa are also becoming significant recipients of 2023 French FDI, emphasizing the continent's growing role as a target for French firms.

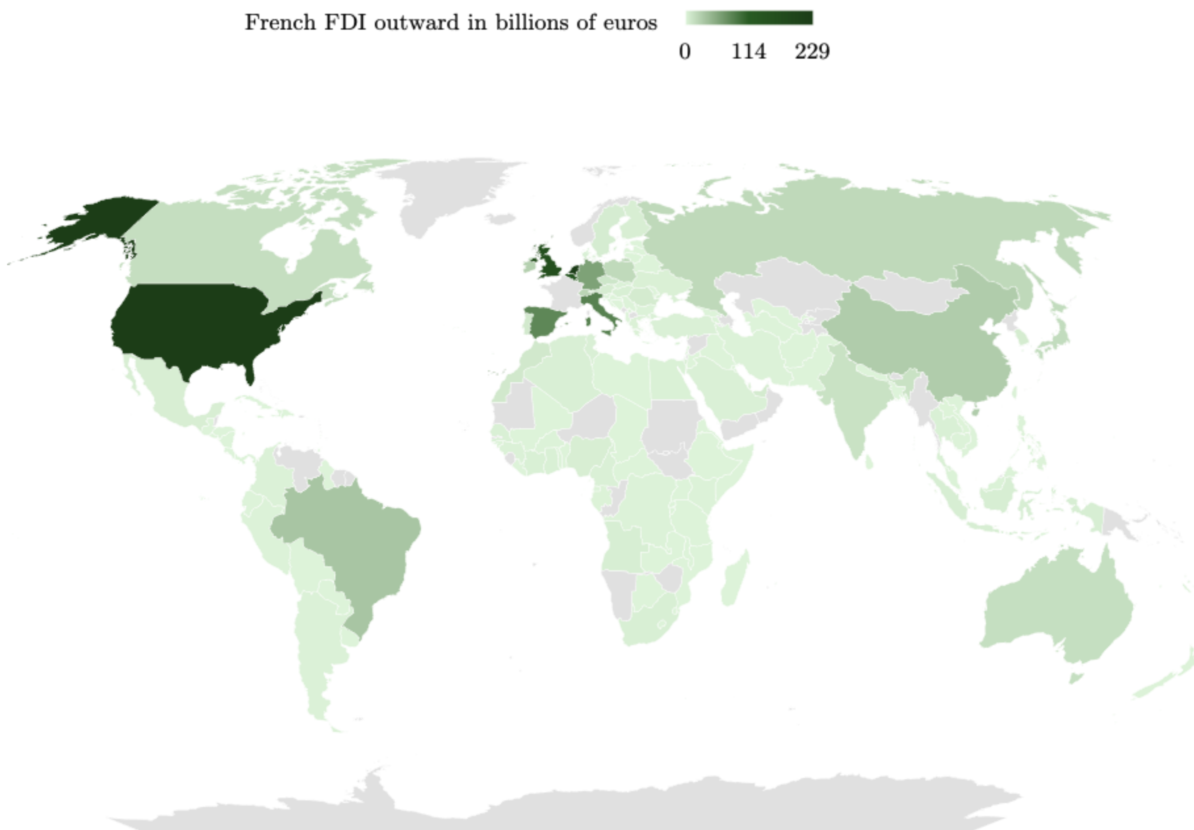


Figure 5: French FDI outward flows in the world

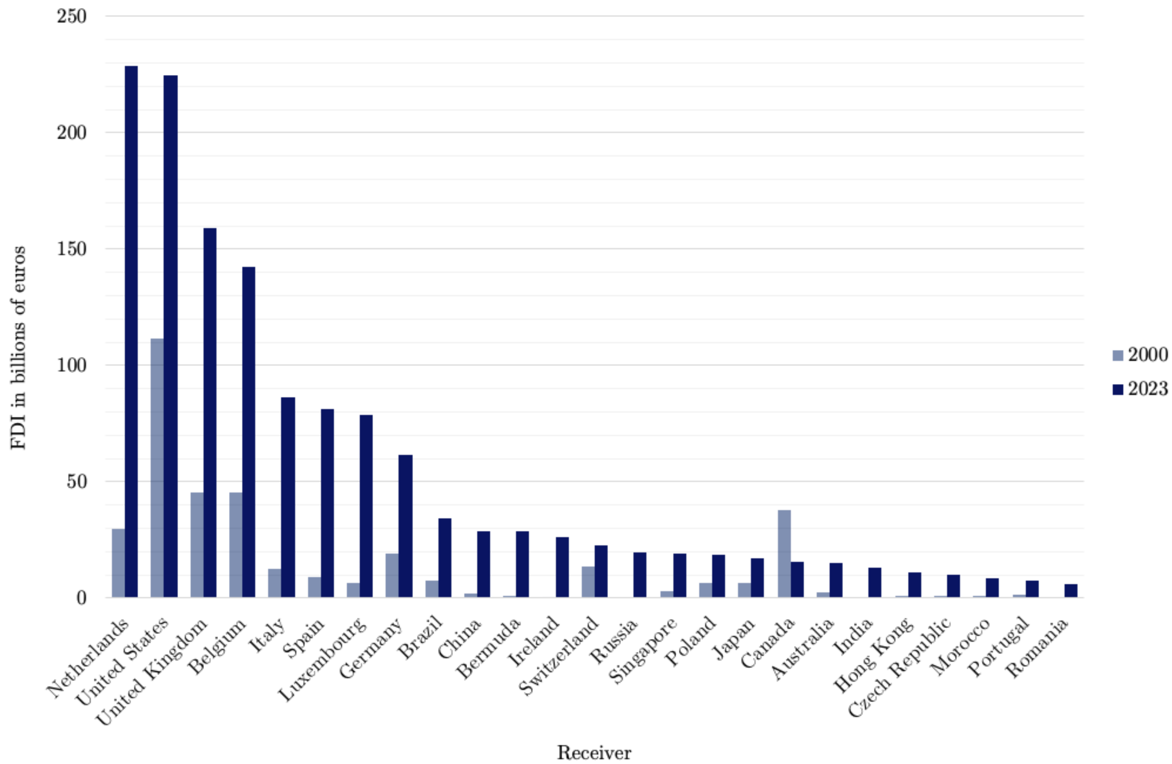


Figure 6: French FDI outward flows in 2000 and 2023

2.4 Insights into the Underlying Effects

The increasing stock of outward FDI seems to align with broader globalization trends, but it may also indicate the relocation of polluting activities, particularly in the manufacturing sector. Although it is difficult to definitively conclude that this reflects a deliberate strategy of shifting environmentally harmful activities abroad, the data show that outward FDI is concentrated notably in the pharmaceutical, textile, and automotive sectors, known for their significant environmental impact. Also, between 2000 and 2015, the share of direct emissions produced within France in these sectors steadily declined, reflecting a growing reliance on GVCs. This shift suggests that a larger proportion of emissions now comes from imported inputs, reinforcing the potential presence of a pollution haven phenomenon, where industries may relocate to countries with more lenient environmental standards. Section 2.3 identifies the growing focus on emerging markets, particularly within the BRICS group, and an increasing interest in African countries. These regions are known for offering competitive advantages in terms of lower labor costs and less stringent environmental regulations.

Regarding the technique effect, it is harder to quantify directly from these descriptive statistics. However, the steady increase in inward FDI over the period under review suggests that foreign capital continues to strengthen France's industrial base, contributing to technological advancements and productivity growth. Inward FDI has been instrumental in supporting innovation, job creation, and knowledge transfer in key sectors of the French economy. Nevertheless, the slower growth of inward FDI compared to the expansion of outward flows raises important questions about the long-term impact of offshoring on the domestic labor market and environmental policies.

3 Measuring the Pollution Embodied in French FDI

To better understand the apparent divergence between French production and emissions, we limit our analysis to the manufacturing sector for three main reasons. First, it is the primary recipient of FDI, making it a key sector to evaluate the environmental impact of globalization. Second, although industries like finance and real estate attract substantial foreign investment, their contribution to emissions remains relatively minor. Finally, while sectors such as transport and construction are significant polluters, their limited mobility due to infrastructure constraints makes them less relevant to the dynamics of offshoring and emissions displacement.

3.1 Tracking Emission Shifts: Levinson's Approach

Our analytical framework is based on the methodological framework established by Levinson (2023), who studied the evolution of pollution embodied in trade over time. To assess the extent to which high-income countries reduce domestic pollution by importing emissions-intensive products, he employs a multi-step accounting exercise. First, his approach requires calculating the total pollution generated during the production of each manufactured product. This is achieved by dividing the total pollution emitted during production by the product's total value, resulting in a metric for emissions intensity, expressed in tons of pollution per dollar of product sold. Then, he estimates pollution displacement by multiplying emission intensity by the value of imported goods, indicating how much pollution would have been produced if these goods had been made domestically. Finally, summing this displaced pollution across all imports gives the total outsourced pollution, representing the pollution avoided through trade.

3.2 Measuring Pollution Displacement via FDI

In our analysis, we adapt Levinson's methodology to focus on outward FDI rather than trade. Although trade data can reveal the pollution displaced by imports, FDI data are more suitable to capture the relocation of production processes abroad. By analyzing where French firms establish or expand their manufacturing operations, we can better assess the extent to which pollution is effectively offshored to countries with lower environmental and labor standards. This approach aligns with Levinson's perspective, which defines outsourcing as the substitution of domestic production with foreign imports. However, imports alone do not necessarily reflect a shift in production, as they can also be driven by consumer preferences for foreign varieties or by broader trade patterns unrelated to firms' location decisions.

Using FDI as an indicator presents several advantages. First, it provides a clearer signal of structural and long-term shifts in production, whereas trade flows can fluctuate due to short-term economic cycles, exchange rate variations, or temporary trade policies. Second, FDI captures corporate decision-making regarding production relocation, while imports are largely shaped by demand-side factors such as consumer preferences for specific foreign goods. Finally, unlike imports, FDI allows us to isolate the role of environmental regulations in shaping firms' offshoring strategies, revealing whether firms actively relocate pollution-intensive activities to countries with laxer environmental standards.

3.3 Methodology and Data

To determine the total amount of pollution embodied PE_{ijt} from country i to country j at time t, we first calculate the ratio of French CO2 emissions to output for each sector (k) to evaluate the emissions intensity. We then multiply this ratio by the amount of FDI sent from country i to country j in the given sector at time t, as expressed in the following equation:

$$PE_{ijt} = \sum_{k=1}^{K} \left(\frac{CO_2Emissions_{mkt}}{Output_{mkt}} \times Outward\, FDI_{ijkt} \right) \tag{1}$$

The index m can take the value FRA or j, meaning that emissions intensity can be considered from French perspective or the one of the destination country, depending on the focus of the analysis. Similarly, t can either vary between 2000 and 2015 when accounting for temporal changes in emissions intensity or be fixed at 2015 when assuming constant emissions intensity. Taking 2015 as the reference year is motivated by two key reasons. First, it aligns with Levinson's study, which uses 2017 constant US emissions intensity. Given that France's emissions intensity in 2015 is expected to be quite similar to that of 2017, this approach offers a solid basis for comparison. Second, to identify the composition effect in section 4.2.1, we need to compute constant foreign emissions intensity. However, emissions intensity data for certain sectors in African and Asian regions are incomplete for earlier periods. As shown in Appendix B1, 2015 provides a more consistent and comprehensive dataset for these regions, making it the most reliable choice.

Data for CO2 emissions, both direct and indirect, as well as output figures, are sourced from the Resolved Multi-Regional Input-Output (RMRIO) database, developed by Cabernard and Pfister (2021) and cleaned up by De Melo and Solleder (2023). This database covers 189 countries and 163 sectors from 1995 to 2015, making it one of the most comprehensive databases available to analyze emissions by sector and country. The sectors in this database are classified according to the EXIOBASE classification system. For sector-level FDI data, we rely on information from the

Banque de France, which provides detailed statistics on both inward and outward investments by sector and destination. The sectors in this dataset are organized according to the International Standard Industrial Classification of Economic Activities (ISIC).

Given the different classification systems used in the two datasets, we needed to adjust the emissions database to align it with the ISIC format. This harmonization process ensured consistency and comparability between datasets. Table 2 displays the sectors included in our study.

Table 2: Frequency Distribution of Activity Codes

Activity Code	Frequency	Percent	Cumulative
C10, C11, 12	764	2.62	6.32
C13, C14	615	2.11	10.77
C16, C17, C18	577	1.98	12.75
C19	491	1.69	14.44
C20	767	2.63	19.84
C21	727	2.50	22.33
C22	587	2.02	24.35
C24, C25	718	2.47	29.50
C26	716	2.46	31.96
C28	699	2.40	34.36
C29	740	2.54	36.90
C30	609	2.09	41.65

Source: Authors calculations.

3.4 An Advanced Database for Refined Analytical Exploration

Our study offers a significant refinement to Levinson's original model by incorporating country- and year-specific data on CO2 emissions, capturing more precise variations in emissions intensity, both across countries and over time. His approach, though a carefully reasoned choice, relied solely on the US Environmental Protection Agency's National Emissions Inventory (NEI), using US based emissions intensity from 2017 across all countries in his analysis. This simplification allowed the author to work with highly detailed industry data but had the trade-off of assuming that all imports and exports were produced under US technological conditions. However, the author notes that access to a similarly detailed international dataset would enable a more precise understanding of pollution intensities across different countries.

This refinement is crucial, as countries vary significantly in their emissions intensity due to differences in technology, policy, and production costs. While some countries benefit from advanced, low-emission technologies that allow them to generate lower emissions per unit of production, these processes are often more costly. On the other hand, countries with higher emissions intensity may rely on production methods that emit more per unit but are significantly less expensive. This disparity makes it advantageous for companies to offshore production to these high-intensity countries, as they benefit from lower production costs despite the higher environmental impact. Accounting for these variations in emissions intensity by country is therefore essential to accurately assess the impact of offshoring on global emissions, as it reveals the economic motivations behind production shifts alongside their environmental consequences.

To capture the effects of both uniform and country-year specific emissions intensity, our analysis is divided into two parts. In section 4.1, we replicate Levinson's approach, assuming all countries operate with the same emissions intensity as France. Additionally, we use a constant emissions intensity, taking 2015 as the reference year. In section 4.2, we refine the analysis by introducing variations in emissions intensity by country of destination j and by year t allowing us to distinguish between composition and technique effects.

The result is a comprehensive view of offshored emissions, revealing how production efficiency varies between the assumed uniform emissions intensity and real-world country-specific intensities. By incorporating both time- and country-specific emissions factors, the study uncovers critical insights into the true nature of decoupling. In particular, comparing the first approach with the second allows us to perform a direct assessment of emissions that would have been produced in France versus those generated abroad. This comparison may demonstrate that, from a global perspective, stricter environmental regulations—often implemented independently in developed countries—could inadvertently lead to higher emissions, as CO2 is a globally shared pollutant.

4 Results

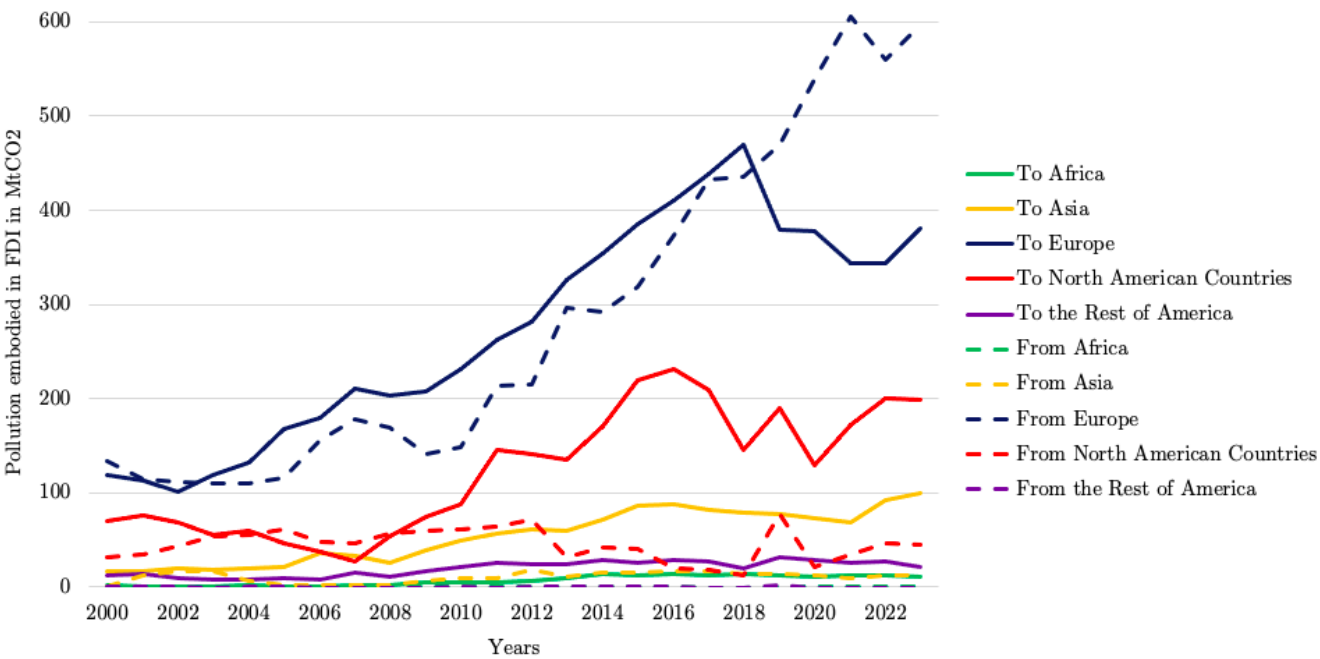
4.1 Emissions embodied in FDI : An Application of Levinson's Approach

Figure 7 presents the estimation results using the methodology proposed by Levinson (2023) using constant 2015 French emissions intensity as below :

$$PE_{ijt} = \sum_{k=1}^{K} \left(\frac{CO_2Emissions_{FRA,k}}{Output_{FRA,k}} \times Outward\ FDI_{ijkt} \right) \tag{2}$$

The solid lines illustrate the pollution embodied in French outward FDI, reflecting French emissions outsourced to foreign countries. In contrast, the dotted lines correspond to the pollution embodied in inward FDI, highlighting emissions generated by foreign investments located within France.

Figure 7: Pollution embodied in FDI by country group considering 2015 french emissions intensity



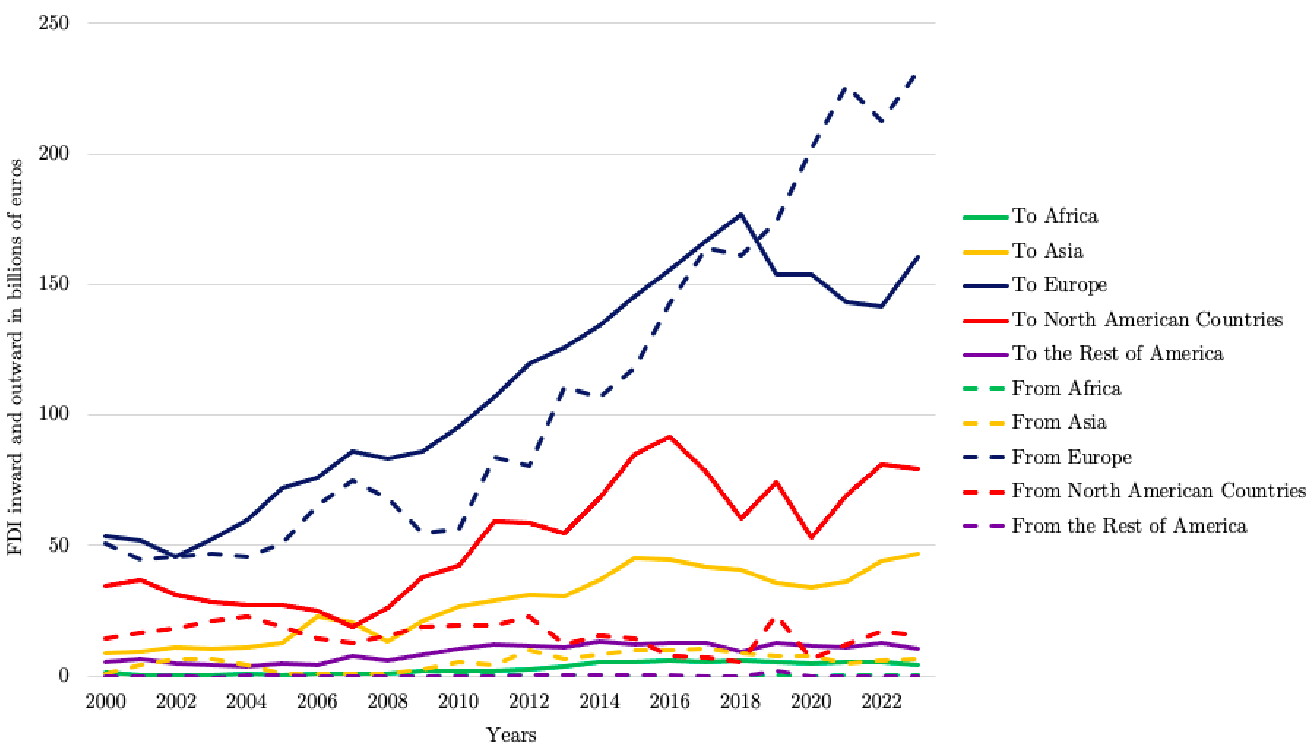
Note: Solid lines refer to PE in outward FDI and dotted lines to PE in inward FDI.

The graph above highlights a consistent upward trend in emissions embodied in FDI over time. One of the most noticeable observations is the exponential increase in emissions embodied in French inward FDI coming from Europe, and also in the corresponding outward FDI, but only until 2016. A less pronounced increase for FDI from France to North America and Asia is observed. For example, emissions related to North American investments intensified from 70 $MtCO_2$ in 2000 to 200 $MtCO_2$ in 2023, while pollution embodied in FDI to Asia saw an increase of about 516%. These changes over time suggest potential relocation effects, as French firms increasingly shift production activities abroad.

Another key feature is the existence of a pronounced gap between emissions embodied in outward versus inward FDI. For instance, emissions linked to French FDI in North America climbed to 200 $MtCO_2$ by 2023, while emissions from North America to France remained relatively low (44 $MtCO_2$). Similarly, emissions associated with French FDI in Asia increased post-2008, reaching 100 $MtCO_2$ in 2023, far exceeding emissions from Asian FDI in France, which stayed comparatively low. This imbalance indicates that French firms might be offshoring some activities to these regions, potentially due to less stringent environmental regulations or more cost-efficient production practices.

However, it has to be acknowledge that the increase in emissions cannot be exclusively attributed to the offshoring of polluting activities. The graph above illustrates two key effects: the scale effect, which captures changes in the overall volume of FDI, and the composition effect, which reflects shifts in the industries contributing to that total FDI volume. Thus, the graph must be interpreted with caution. The disparity in emissions may partly stem from variations in FDI volume itself, as France could be investing more in these regions than it receives in return. This larger outward flow of investment naturally correlates with higher embodied emissions, according to the scale effect.

Figure 8: FDI by countrygroup between 2000 and 2023



Note: Solid lines refer to outward FDI and dotted lines to inward FDI.

Figure 8 confirms the fact that the trends in FDI remain very similar to those observed in Figure 7 for embodied emissions, especially the surprising result that pollution embodied in inward FDI from Europe to France has, at times, surpassed outward FDI emissions from France to other European countries. This finding is largely explained by the fact that, since 2019, France has been attracting more European FDI than it has been sending abroad (UNCTAD, 2024). Consequently, we can conclude that the pollution embodied in FDI is predominantly influenced by the volume of investment flows between country groups, rather than by the specific nature of the investments themselves. This observation points more towards a scale effect than a composition effect, reinforcing Levinson (2023) findings.

Table 3 strikingly illustrates the similarity in the trends of pollution emissions embodied in FDI (column 1) and FDI (column 2) flows from 2000 to 2023. In most cases, the percentage growth in pollution emissions closely mirrors that of FDI flows, suggesting a strong interdependence between FDI volumes and the associated pollution levels. The correlation coefficient, which equals 97%, confirms this close relationship. Such a high correlation indicates that fluctuations in pollution emissions can largely be explained by changes in FDI flows, reinforcing the relative importance of the scale effect.

Table 3: Percentage Changes in Embodied Pollution and FDI Across Regions from 2000 to 2023

Region	PE	FDI
To Africa	386%	252%
To Asia	516%	437%
To Europe	221%	200%
To North America	183%	129%
To the Rest of America	80%	86%
From Africa	-61%	-12%
From Asia	1197%	847%
From Europe	344%	355%
From North America	39%	7%
From the Rest of America	-14236%	-2046%
Correlation Coefficient	97%	

Note: PE denotes Pollution Embodied in French production.

Source: Authors calculations.

4.2 Dynamic Assessment of Emissions Intensity Across Countries and Years

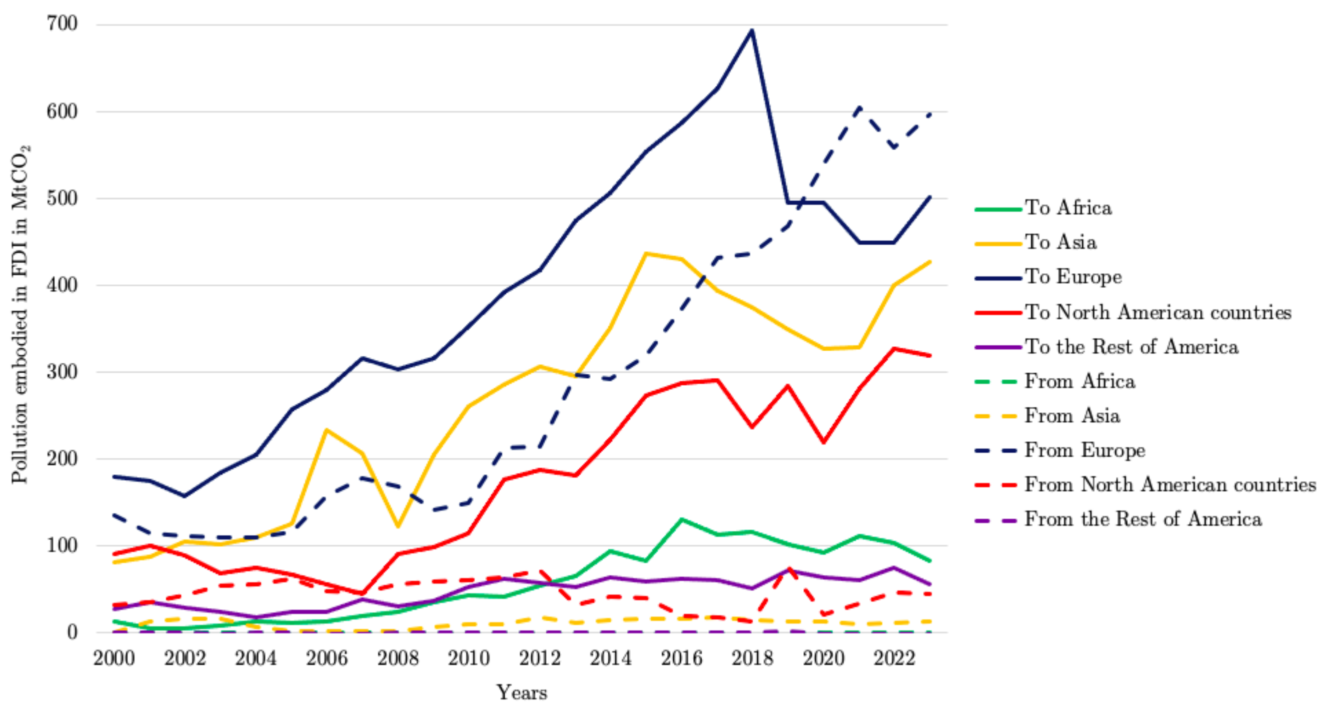
The results in the previous section do not fully explain the simultaneous observed rise in French production coupled with a decrease in French emissions. While emissions embodied in FDI have increased, supporting evidence of a scale effect, neither a composition effect nor a technique effect could be identified. As a result, the factors driving the reduction in French emissions remain unexplained and open to multiple interpretations. This section seeks to build on this by examining two dimensions of emissions intensity heterogeneity. It examines how FDI emissions intensity differs among countries and how these differences evolve over time. Examining these two aspects may help uncover evidence of a composition effect and/or a technique effect, offering a clearer understanding of the mechanisms behind French emissions trends.

4.2.1 Identification of a Composition Effect

Figure 9 reports the results based on the constant 2015 emissions intensity of the destination country j. We intentionally make this assumption to isolate the composition effect, since allowing for both country- and time-specific heterogeneity in the same figure would blur the distinction between composition and technique effects. So, we start by allowing for country heterogeneity using the following formula :

$$PE_{ijt} = \sum_{k=1}^{K} \left(\frac{CO_2Emissions_{jk}}{Output_{jk}} \times Outward\,FDI_{ijkt} \right) \tag{3}$$

Figure 9: Pollution embodied in FDI by countrygroup with destination country emissions intensity



Note: Solid lines refer to outward FDI and dotted line to inward FDI.

Integrating the emissions intensity of destination countries into the analysis of pollution embodied in FDI reveals both, strong similarities and notable differences. Figure 9 illustrates a clear scale effect, showing a steady rise in emissions tied to FDI over time. This effect is especially prominent in emissions within Europe and in French FDI directed toward Asia and North America.

Accounting for the emissions intensity of destination countries also highlights a wider gap between emissions from outward and inward FDI. For instance, the pollution embodied in French FDI to Asia is now 27 times higher than that from Asian investments in France, a substantial increase from the fivefold difference observed in Figure 7 under Levinson (2023) approach. This comparison underscores the significant impact that using destination countries' emission intensity has on the environmental effects of investment flows. When turning to Africa, while the emissions embodied in FDI are still modest compared to other regions, there has been a noticeable increase over the past decade, widening the gap between African investments in France and French FDI directed toward Africa. This gradual rise suggests a potential shift, with French firms relocating some production to African markets, possibly motivated by cost advantages.

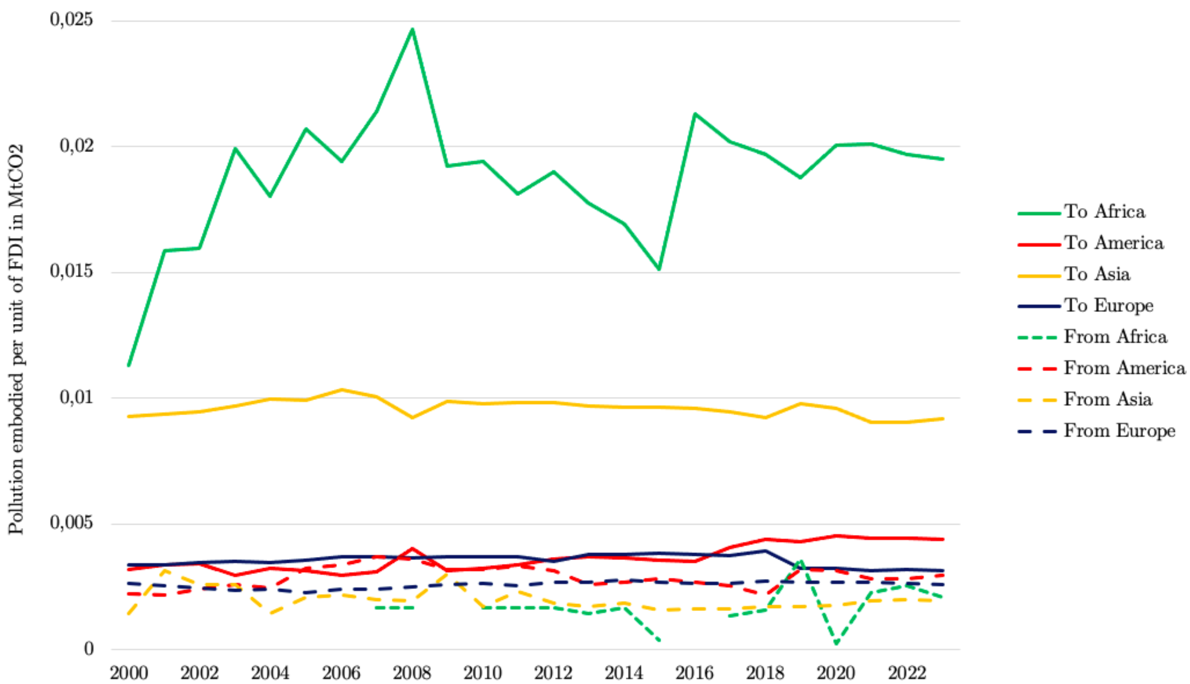
A critical question remains: does accounting for the emissions intensities of destination countries help us identify a composition effect? Comparing Figure 9, which highlights emissions embodied in FDI, with Figure 8, which illustrates total FDI stocks, reveals clear differences. Notably, although French FDI flows more heavily toward North America than Asia, emissions associated with French FDI are significantly higher in Asia, suggesting that French investments in Asia are concentrated in more pollution-intensive sectors. This pattern also appears when comparing Africa with Central and South America. Despite Africa receiving lower overall FDI, the continent hosts investments with higher pollution intensity than those in Central and South America. This difference implies that French investments in Africa may be more concentrated in pollution-intensive industries, possibly due to the region's relatively lax environmental regulations. Finally, considering the varying emissions intensities of destination countries indicates not only the presence, of a scale effect, but also of a composition effect. These findings support the broader understanding that offshoring frequently targets countries with more lenient regulations, allowing firms to circumvent the stricter environmental standards imposed in France.

To gain deeper insights into this composition effect, we compute weighted averages of industry-specific emissions intensities by dividing the pollution embodied in FDI by the total amount of country i FDI directed to each destination country j :

$$per\ unit\ PE_{ijt} = \frac{\sum_{k=1}^{K} \left(\frac{CO_2 Emissions_{jk}}{Output_{jk}} \times \ FDI_{ijkt} \right)}{\sum_{k=1}^{K} FDI_{ijkt}} \tag{4}$$

These ratios capture the distribution of FDI across sectors and allow us to identify which types of FDI are most often relocated to each region. If the pollution embodied per unit of French FDI is high, it means France is relocating more polluting FDI, and if the FDI coming into France from the destination region is lower, both factors together confirm a composition effect.

Figure 10: Weighted average of industry-specific emissions intensities



Note: Solid lines refer to outward FDI and dotted line to inward FDI.

The composition effect, as illustrated by the positions of the solid and dotted lines in Figure 10, is particularly noticeable in French FDI directed toward Africa and Asia, where emissions are significantly higher compared to emissions from FDI originating in these regions and directed toward France. Specifically, French FDI in Africa is 9 times more polluting per unit than that of African FDI in France, while for Asia, it is 5 times more polluting. By contrast, this gap is narrower for regions like Europe (1.2 times) and America (1.5 times), indicating that France is not extensively offshoring pollution-intensive activities to these more developed areas. These disparities point to a marked tendency for French firms to concentrate their more environmentally harmful activities in emerging and developing economies, where regulatory standards tend to be less stringent than those in Europe or America. This result aligns with the previous literature on carbon leakages, which states that developed countries are net importers of emissions, while developing nations are net exporters (Peters et al., 2011; Cezar and Polge, 2020; Wood et al., 2020).

4.2.2 Identification of a Technique Effect

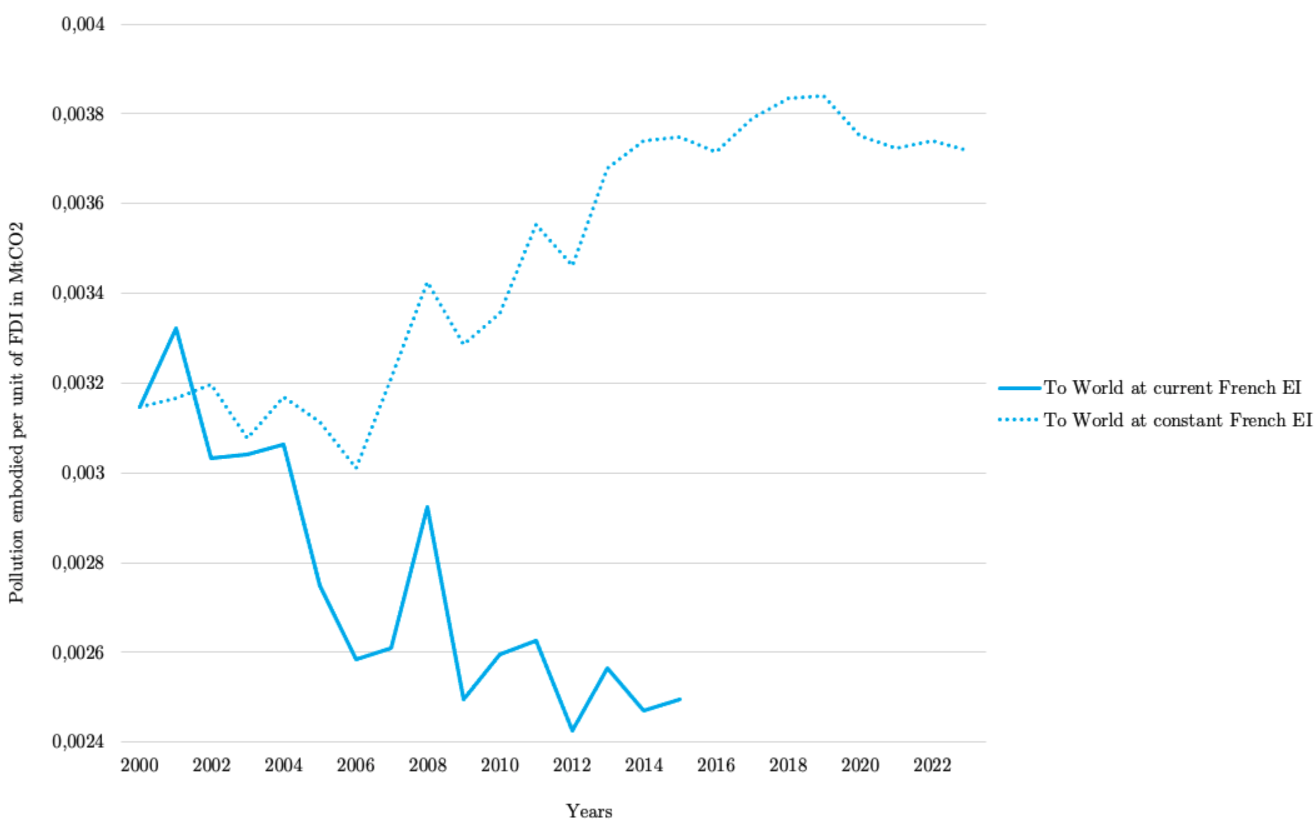
The availability of detailed data on CO2 emissions and sector-specific production over time allows for a comprehensive analysis of the dynamics of emissions intensity. This section aims to investigate whether the composition effect identified for France is mitigated by a technique effect, referring to improvements in emissions intensity and production practices. To assess this interaction, we use both constant and current emissions intensity data and interpret any difference between the two as evidence of a technique effect. Furthermore, to better understand the decoupling process in the French case, we slightly depart from the previous section by focusing on France's own emissions intensity rather than that of its foreign counterparts. Our results can thus be interpreted as the emissions that would have been generated if France had produced all goods domestically, without any offshoring. This distinction is crucial, as focusing on French emissions intensity specifically allows us to accurately measure the technique effect in the context of France. The equation used to calculate the emissions that would have been generated if France had produced all goods domestically is :

$$per\ unit\ PE_{FRA,jt} = \frac{\sum_{k=1}^{K}\left(\frac{CO_2Emissions_{FRA,kt}}{Output_{FRA,kt}} \times\ FDI_{FRA,jkt}\right)}{\sum_{k=1}^{K} FDI_{FRA,jkt}} \tag{5}$$

with $t = \{2000, 2001, \ldots, 2015\}$ when using current emissions intensity and $t = 2000$ when using constant emissions intensity. Here, using 2000 constant emissions intensity is the best option, as it allows us to analyze the technique effect, with all variations in emissions intensity in subsequent years being measured relative to the initial state of the economy and technology. Moreover, sectoral data on emissions intensity are fully available for France, as shown in Appendix B1.

In these visualizations, the solid line uses annual French emissions intensity, while the dotted line is based on constant 2000 French emissions intensity. As previously explained in Fig. 10, the dotted line, representing pollution embodied per unit of FDI at constant emissions intensity, can only reflect a composition effect. Therefore, any difference between the solid and dotted lines points to the presence of a technique effect.

Figure 11: Composition and Technique Effects for French FDI



Note: Both the solid and dotted lines are computed using French Emissions Intensity (EI), with the solid line using current EI and the dotted line using constant 2000 EI.

The results presented in Fig. 11 are both revealing and insightful. They clearly illustrate the presence of a composition effect, particularly visible in the marked increase of the dotted line between 2000 and 2015, which rises by almost 20%. This increase supports our previous findings using France's own emissions intensity rather than that of destination countries. However, the interpretation of the result is different. The 20% increase in pollution embodied in FDI, measured using France's own production capacities, suggests that France has not only offshored production but has done so in a way that increasingly concentrates on pollution-intensive goods. In reality, considering the higher emissions intensity of many destination countries, the true global impact is likely even greater[1].

On the other hand, the solid line reveals a sharp decline, approximately 20%, which suggests that, without distinguishing between the composition and technique effects, one could incorrectly attribute this drop to other factors. By isolating the difference between the two curves, we observe

[1]See section 4.2.3 for empirical evidence.

that the technique effect accounts for nearly 40% of the decrease, which is twice the magnitude of the composition effect. This finding is well-supported in the literature (Levinson, 2009; Brunel, 2017; Shapiro and Walker, 2018; Copeland et al., 2021), highlighting the predominant role of the technique effect over scale and composition effects. While offshoring via the composition effect has played a role in reducing CO2 emissions within France, the more substantial reductions in emissions are attributed to technique improvements probably driven by innovation.

4.2.3 The Adverse Effect of Offshoring on Emissions: A Comparative Analysis

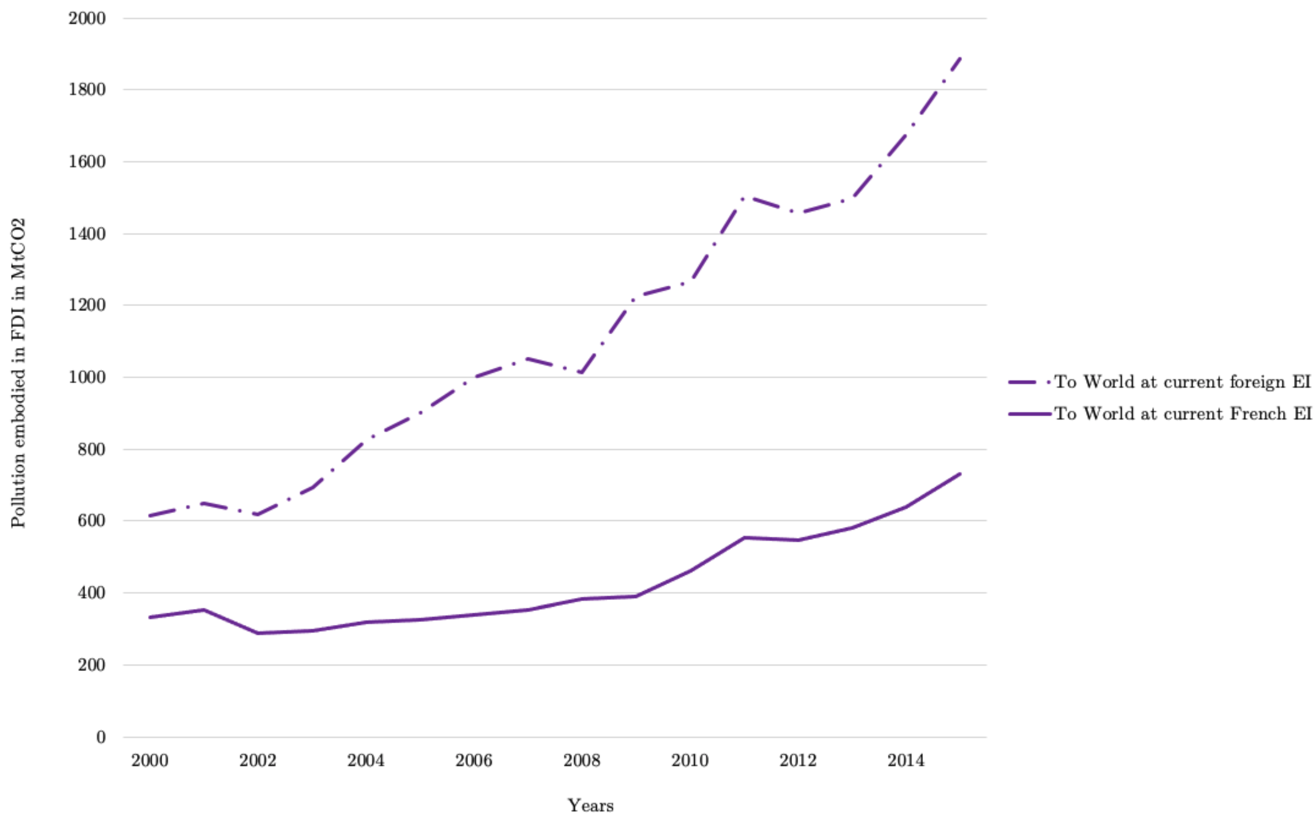
As mentioned in section 4.2.2, France has significantly reduced its environmental footprint by improving its production processes. This is not the case for all countries, making it relevant to explore the difference in pollution between what is actually emitted by offshoring (RPE_{ijt}) and what would have been emitted if France had produced all goods domestically (PE_{ijt}). This section aims to shed light on the pressures faced by firms that drive them to offshore production rather than manufacture in France, potentially revealing evidence of carbon leakage. The following equations are used to analyze this distinction.

$$PE_{FRA,RoW,t} = \sum_{k=1}^{K} \left(\frac{CO_2Emissions_{FRA,k,t}}{Output_{FRA,k,t}} \times Outward\, FDI_{FRA,RoW,k,t} \right) \tag{6}$$

$$RPE_{FRA,RoW,t} = \sum_{k=1}^{K} \left(\frac{CO_2Emissions_{RoW,k,t}}{Output_{RoW,k,t}} \times Outward\, FDI_{FRA,RoW,k,t} \right) \tag{7}$$

Figure 12 illustrates this finding, comparing the actual emissions of French FDI abroad (dashed line) with the hypothetical emissions if production had remained in France (solid line). The data clearly indicate that offshoring has led to a significant increase in emissions. Over time, this gap widens, ultimately showing emissions 2.5 times higher than if production had stayed in France. This finding is critical and should raise concerns among policymakers. The decision to offshore is likely influenced by the stringent environmental regulations imposed on French firms. While this may lead to a reduction in domestic emissions, it comes at the cost of a significant increase in global CO2 emissions. Policymakers must reconsider their approach and critically assess the broader impact of national policies on global climate change. Strengthening international cooperation remains the most effective strategy to achieve a low-carbon economy.

Figure 12: Real Pollution Embodied in FDI vs. Counterfactual Emissions Without Offshoring



Note: Solid line refers to Eq.(6) and dashed line to Eq.(7)

5 The Role of Environmental Regulations in Shaping Firms' Behavior

The previous section highlighted a significant gap between the actual emissions generated by French FDI and the hypothetical emissions that would have occurred had production remained in France. However, at this stage of the analysis, there is no conclusive evidence to suggest that environmental regulations play a major role in driving these results.

This section aims to clarify this uncertainty by developing an empirical model based on French FDI located in 69 different destination countries. To construct the dataset, we move away from the Banque de France's original database, which grouped countries by continent, and instead rely on the World Bank's bilateral FDI data, available for 247 countries from 2001 to 2022. For the purpose of this study, we concentrate on the 2001–2015 period, prior to the implementation of the Paris Agreement. The selected 69 countries represent a robust sample of French FDI abroad, accounting for over 95% of total French outward FDI (see Appendix C1 for the full list of countries).

This section is structured around two key analyses. First, we investigate how environmental regulations, while designed to reduce domestic emissions, may inadvertently contribute to an increase in global CO2 emissions through carbon leakage. By relocating production to countries with weaker environmental standards, French firms may unintentionally increase global pollution, even as domestic emissions decline. To quantify this effect, we study the impact of environmental regulations on the gap between the two lines in Figure 12, comparing the actual emissions generated by French FDI with counterfactual emissions. Second, we analyze the relationship between environmental regulations and technique effects to determine if it provides further insight into our analysis. Specifically, we analyze how environmental regulations influence emissions intensity across our expanded sample, which now includes France. Together, these analyses will form the basis for policy recommendations, advocating for uniform, international environmental regulations over fragmented national approaches. Such an approach is essential to effectively combat the global climate crisis.

To assess the stringency of environmental policies across countries, we use the Environmentally Related Tax Revenues (ERTR) dataset, provided by the OECD. Available at both the sectoral and country levels, this database is one of the most precise tools to gauge the rigor of environmental regulations. The ERTR captures revenues generated from taxes on activities with negative environmental impacts, such as carbon emissions, energy consumption, and pollution. As a market-based policy instrument, it effectively reflects how governments employ fiscal tools to incentivize cleaner production and reduce environmental harm in a given country. The advantage of the ERTR lies in its extensive coverage, consistency, and ability to compare environmental policies across countries and over time.

5.1 Evidence of Carbon Leakage

Table 4 presents the estimation outcomes using a fixed effects model. Regardless of the specification, the dependent variable is simply the difference in the logarithms of the actual emissions embodied in FDI from Eq.(7) and the counterfactual emissions from Eq.(6). In column (1), we examine the effect of both the origin and destination country regulations on the gap between actual emissions and counterfactual emissions in the absence of offshoring. Column (2) investigates how the divergence in environmental regulations influences this gap. Columns (3) and (4) replicate the analysis from columns (1) and (2), but include time fixed effects to control for potential temporal factors. Finally, columns (5) to (8) focus on African and Asian countries to assess whether the impact of regulations differs in these regions, particularly in light of our findings from Figure 10, where we observed that FDI directed to these regions is associated with higher pollution levels.

Table 4: Identification of a carbon leakage effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All countries				**Africa & Asia**			
$Ln(ERTR_{it})$	0.233***		0.345***		0.409***		0.586***	
	(0.0580)		(0.0741)		(0.110)		(0.135)	
$Ln(ERTR_{jt})$	-0.127***		-0.127***		-0.0612**		-0.100***	
	(0.0342)		(0.0341)		(0.0278)		(0.0257)	
$Diff\ Ln(ERTR_{ijt})$		0.110***		0.127***		0.00330		0.100***
		(0.0355)		(0.0341)		(0.0313)		(0.0257)
Observations	973	973	973	973	323	323	323	323
R-squared	0.107	0.082	0.154	0.154	0.225	0.000	0.307	0.307
Number of countries	69	69	69	69	25	25	25	25
Destination FE	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

The results confirm the significant role of environmental regulations in shaping pollution patterns. Both policies in France, the origin country, and the destination countries influence the emissions gap, with French policies exerting a notably stronger impact. A 1% increase in French environmental tax revenue widens the gap by approximately 0.35%, while a similar increase in the destination country's regulations narrows it by 0.13%. Considering the difference in regulatory stringency between countries in column (4) also yields important insights. Harmonized regulations across countries can mitigate carbon leakage, with a 1% reduction in the regulatory gap associated with a 0.127% decrease in the emissions difference.

When focusing specifically on African and Asian destinations, the effect of French environmental policies is even more pronounced. A 1% increase in French regulatory stringency is associated with a 0.59% increase in the emissions gap, compared to 0.35% in the whole sample. Stricter regulations in France can induce firms to adapt, leading to lower emissions intensity domestically, thereby widening the gap in emissions when production is offshored to countries where production methods tend to be more pollution-intensive as Africa and Asia. Conversely, environmental regulations in destination countries play a significantly smaller role, with an impact five times weaker than that of French regulations. This reduced effect can be attributed to the fact that environmental policies in these countries have less influence on emissions intensity, likely due to weaker enforcement, and the presence of mechanisms that allow firms to bypass regulations. Thus, if our reasoning holds[2], the weaker technique effect in African and Asian countries leads to a slower reduction in the emissions gap, as the real pollution embodied in FDI, $Ln(RPE_{ijt})$ decreases at a slower pace.

Introducing time fixed effects in columns (3)-(4) and (7)-(8) substantially improves the model's

[2]This effect is actually empirically demonstrated in part 5.2

explanatory power. The R-squared increases from 0.107 to 0.154 for all countries, and from 0.225 to 0.307 for Africa and Asia. This improvement suggests that time-specific factors account for approximately 31% of the variation in the emissions gap for all countries, and 27% for Africa and Asia. Appendices C4 and C5 reveal that time-fixed effects coefficients exhibit a clear upward trend, indicating that factors beyond firm- and country-specific characteristics have contributed to changes in pollution embodied in FDI over time. The financial crisis of 2008 appears to coincide with a temporary dip, possibly reflecting reduced industrial activity. In developing economies, the time-fixed effects show a much steeper increase, which may reflect the rapid industrialization these economies experienced during this period.

5.2 A Technique Effect Suggestive of a Porter Effect

In the previous section, we established that environmental regulations significantly influence the pollution gap between offshored production and domestic production in France. Notably, we found that French regulations have a more substantial impact on this gap compared to the regulations in host countries. Building on these results, we postulate that these effects are primarily driven by what is known as the technique effect. In this section, we aim to investigate whether countries indeed reduce their emissions intensity when governments increase environmental taxes and regulations on firms, thereby lowering the emissions embodied in FDI. Our findings may provide evidence in support of the Porter Hypothesis, which posits that well-designed environmental regulations, especially market-based policies, can stimulate innovation and enhance competitiveness, potentially leading to both environmental and economic benefits.

Table 5: Identification of a technique effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	All countries		**Africa and Asia**		**Europe**		**North America**		**Latin America**	
$Ln(ERTR_{jt})$	-0.509***	-0.129***	-0.355***	-0.100***	-0.810***	-0.275***	-1.214*	-0.581***	-0.333**	-0.132**
	(0.0641)	(0.0344)	(0.0553)	(0.0257)	(0.0759)	(0.0527)	(0.175)	(3.90e-06)	(0.128)	(0.0599)
Observations	992	992	323	323	460	460	30	30	175	175
R-squared	0.537	0.846	0.543	0.794	0.742	0.956	0.911	0.991	0.352	0.755
Number of countries	70	70	25	25	31	31	2	2	12	12
Destination FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5 presents the results, with the odd-numbered columns showing the outcomes without time-fixed effects, and the even-numbered columns incorporating them. Regardless of the country's economic classification, we find that environmental regulations significantly contribute to reducing emissions intensity. A 1% increase in environmental taxes encourage firms to innovate and adopt cleaner production processes, leading to a measurable decline of 0.12% in emissions intensity when considering country and time fixed effects (column (2)). However, the effect varies across regions. In developed economies, particularly in Europe and North America, environmental regulations are notably more effective. A 1% increase in environmental tax stringency leads to a reduction in emissions intensity of 0.28% in Europe and 0.58% in North America (columns (6)-(8)), highlighting the strong influence of well-enforced policies in these regions. However, in emerging and developing economies across Africa, Asia, and Latin America, the effect is more nuanced. For these regions, a 1% increase in regulatory stringency results in a 0.10% reduction in emissions intensity, which is less than half the effect observed in developed countries. This disparity may be attributed to differences in regulatory enforcement, as environmental regulations in some developing and emerging economies may be less strictly implemented. Finally, these results help explain the findings on carbon leakage presented in the previous section and offer evidence supporting the existence of a Porter effect.

6 Concluding Remarks

This study aimed to investigate the paradoxical relationship between the increase in French production and the simultaneous decline in emissions over time. Three mechanisms were considered to explain this divergence: the scale effect, where more FDI leads to higher emissions, the composition effect, as pollution-intensive production shifts abroad, and the technique effect, with innovations reducing emissions per unit of output.

By building on Levinson (2023) framework and adapting it to the French context through the lens of FDI, we find results consistent with his findings. Our analysis highlights a strong scale effect, driven by the expansion of French outward FDI. However, the composition effect remains less evident under his approach.

To better understand the dynamics, we expanded the analysis by integrating a more sophisticated dataset on emissions, accounting for country-specific and time-varying emissions intensities. This allowed us to identify both a composition and a technique effect, in addition to the scale effect already documented. The composition effect became evident when examining FDI flows to regions such as Asia and Africa, where environmental regulations are less stringent, making these regions attractive for pollution-intensive industries. This indicates that offshoring has played a significant role in reducing emissions within France while potentially increasing emissions abroad. Furthermore, we are able to identify a clear technique effect. This effect is even more pronounced than the composition effect, indicating that technological changes and innovation play a crucial role in driving emission reductions, highlighting the importance of technological progress in sustainable production practices.

To conclude, while France has succeeded in reducing its domestic emissions, part of this achievement may be attributable to the externalization of pollution to countries with less stringent environmental standards. At the same time, the technical improvements identified suggest that cleaner technologies are playing an increasingly important role in mitigating the environmental impact of both domestic and international production.

By disentangling these effects, our study provides a clear framework to understand the broader implications of environmental policies, particularly their impact on firm behavior and international trade dynamics. We develop a small empirical model to examine the role of environmental regulations in carbon leakage and technique effects. Our results provide robust evidence that can guide policymakers. Specifically, through the lens of the technique effect, environmental regulations can reduce the pollution embodied in FDI. When effectively enforced and uniformly implemented across countries, such regulations play a crucial role in addressing the climate crisis and mitigating carbon leakage.

Although our study provides valuable insights, future research should focus on a more detailed analysis, particularly through the use more disaggregated data that go beyond broad sectors. As identified by Levinson (2023), dividing the data into only 12 manufacturing sectors might either overestimate or underestimate the pollution associated with FDI activities. A more granular database would provide a clearer picture of emissions across different industries, enhancing the precision of the analysis. Moreover, the availability of data only until 2015 restricts the evaluation of emissions by country and hinders the assessment of the technique effect, which could be more visible in recent years. With the increasing environmental rigor following the Paris Agreements, it is likely that more significant re-allocations of production emerged in subsequent years, calling for further investigation to examine and evaluate these developments.

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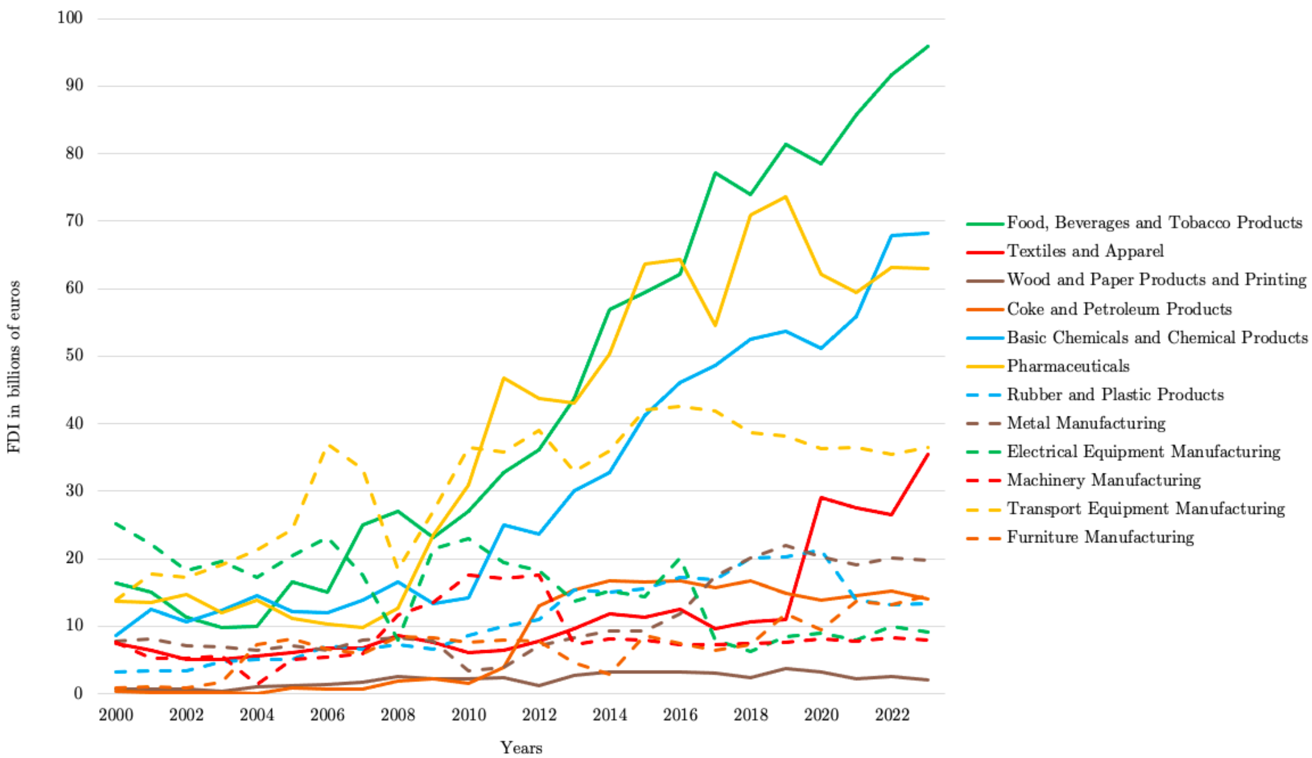
Appendix

Appendix A: FDI Top Sectors

Figure A1: Evolution of French manufacturing FDI outward from 2000 to 2023



Appendix B: Emissions Intensity Data Coverage

Table B1: Emissions Intensity by countrygroup and year

Year	**Asia**	**Africa**	**France**	**World**
2000	7	4	12	12
2001	8	2	12	12
2002	8	2	12	12
2003	8	3	12	12
2004	7	3	12	12
2005	9	3	12	12
2006	8	4	12	12
2007	8	5	12	12
2008	10	5	12	12
2009	11	7	12	12
2010	11	8	12	12
2011	12	6	12	12
2012	12	5	12	12
2013	12	12	12	12
2014	12	12	12	12
2015	12	11	12	12

Appendix C: Empirical Model

Table C1: List of countries

Europe	**Africa**	**Latin America**	**Asia and Pacific**	**North America**
Austria	Cameroon	Argentina	Australia	Canada
Belgium	Congo, Rep	Bahamas, The	Bangladesh	United States
Bulgaria	Cote d'Ivoire	Brazil	China	
Croatia	Egypt, Arab Rep.	Chile	Hong Kong	
Cyprus	Gabon	Colombia	India	
Czech Republic	Israel	El Salvador	Japan	
Denmark	Kenya	Mexico	Korea, Rep.	
Estonia	Mali	Panama	New Zealand	
Finland	Mauritius	Paraguay	Pakistan	
France	Morocco	Peru	Philippines	
Germany	Nigeria	Uruguay	Singapore	
Greece	Senegal	Venezuela, RB		
Hungary	South Africa			
Ireland	Uganda			
Italy				
Kazakhstan				
Latvia				
Lithuania				
Luxembourg				
Netherlands				
Norway				
Poland				
Portugal				
Romania				
Slovak Republic				
Slovenia				
Spain				
Sweden				
Switzerland				
Ukraine				
United Kingdom				

Table C2: Summary Statistics to Estimate the Carbon Leakage

Variable	Obs	Mean	Std. Dev.	Min	Max
$Year$	973	2008.145	4.293809	2001	2015
$Diff\ Ln(PEinFDI_{ijt})$	973	0.7801875	0.6133462	-0.6190279	3.088759
$Ln(ERTR_i)$	973	10.86752	.2174627	10.31669	11.08222
$Ln(ERTR_j)$	973	7.575359	2.246971	-2.432957	11.83138
$DiffLn(ERTR_{ijt})$	973	3.292158	2.233053	-1.19857	12.88016

Table C3: Summary Statistics to Estimate the Technique Effect

Variable	Obs	Mean	Std. Dev.	Min	Max
$Year$	992	2008.162	4.296864	2001	2015
$Ln(EI_j)$	992	-0.6749531	0.6798565	-2.250074	2.194321
$Ln(ERTR_j)$	992	7.622774	2.262836	-2.432957	11.83138

Figure C4: Evolution of year dummies for the whole sample

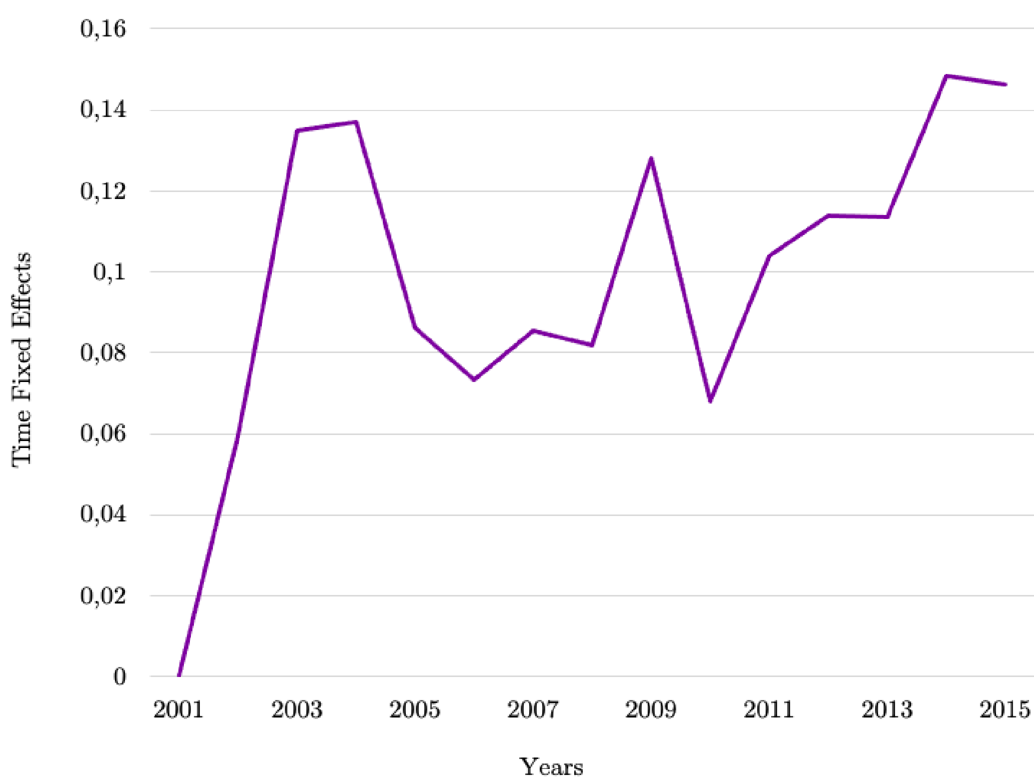


Figure C5: Evolution of year dummies for Africa and Asia