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Assessing the environmental impact of trade agreements using the gravity model: the case of the EU-Mexico free trade agreement

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Summary

International trade is a recognised driver of economic growth, yet its environmental consequences have received far less systematic attention. Free trade agreements alter not only how much countries trade, but also its composition and direction, thereby reshaping the geographical distribution of emissions embodied in traded goods. Environmental evaluations of EU trade agreements continue to rely almost exclusively on ex ante computable general equilibrium simulations, which derive outcomes from imposed structural assumptions rather than from observed post-agreement adjustments. This thesis addresses that gap by developing an ex post empirical framework that links realised trade reallocation to changes in embodied CO_2 emissions, applied to the EU-Mexico Free Trade Agreement, which entered into force in 2000.

The central research question examines the extent to which the EU-Mexico FTA influenced trade flows and the distribution of embodied CO_2 emissions between the European Union, Mexico, and third-country partners. Using OECD ICIO-TiVA data on bilateral trade and embodied emissions, this thesis estimates a structural gravity model by Poisson Pseudo-Maximum Likelihood with three-way fixed effects, two post-treatment interactions capturing bilateral trade creation and third-country spillovers, and a time-varying control for other preferential trade arrangements. Parallel gravity models for trade and embodied emissions are estimated under identical specifications, and the resulting coefficients feed into a scale-composition-technique decomposition that traces how the agreement's economic effects propagated into environmental outcomes.

The analysis yields three principal findings. First, the FTA generated bilateral trade creation of 26.4% and a positive third-country spillover of 21.0%, with no evidence of trade diversion. Second, embodied CO_2 emissions along the bilateral margin rose by 17.8%, less than proportionally to trade. The 8.6 percentage-point gap suggests that the increase in bilateral trade was concentrated in relatively cleaner sectors and/or accompanied by declining within-sector emission intensities. Along the spillover margin, trade and emissions effects are nearly proportional, implying that the agreement did not systemically redistribute carbon-intensive production toward or away from third countries. Third, the environmental transmission is structurally asymmetric: scale pressure along the EU-to-Mexico direction is offset mainly through declining within-sector emission intensities, while along the Mexico-to-EU direction the offset operates primarily through a compositional shift toward cleaner sectors.

This thesis provides the first ex post econometric assessment of the EU-Mexico FTA's environmental consequences based on observed data, and integrates structural gravity estimation with input-output-based environmental accounting in a single replicable framework. In doing so, it qualifies existing CGE-based evaluations that conclude environmental effects are negligible, and offers a tractable alternative to simulation-based environmental evaluation in an era where climate objectives are increasingly central to EU trade policy.

Preface

The choice of this thesis topic emerged from two developments that have significantly shaped the political and economic climate in recent years. The first is the steadily growing importance of environmental considerations in policymaking, as the question of how economic activity translates into ecological pressure has moved from the margins of academic debate to the centre of public discourse. The second is the resurgence of geopolitical tension surrounding international trade. Most notably, the return of Donald Trump to the United States presidency has been accompanied by a rise in tariff threats, retaliatory measures, and a broader scepticism toward the multilateral trading system. Together, these developments make the relationship between trade policy and environmental outcomes a particularly pertinent subject for empirical investigation.

The selection of the EU-Mexico Free Trade Agreement was partly pragmatic. The OECD ICIO-TiVA data extend only to 2018, and the agreement's 2000 entry into force places it comfortably within that window with five pre-treatment and six post-treatment years available for the analytical sample. At the same time, the EU-Mexico case proved genuinely interesting in its own right: it is one of the EU's longest-standing comprehensive trade agreements, it links partners at very different income levels and at different positions in global value chains, and its environmental consequences had never been assessed using observed data rather than simulation. In this sense, the EU-Mexico case offers a grounded empirical perspective on the broader question of how trade integration affects the geographical distribution of emissions.

Lastly, I would like to thank my supervisor, Prof. dr. Glenn Rayp, for his guidance throughout this project, for the precision of his feedback at each stage, and for the freedom he gave me to develop the empirical strategy in my own way while keeping me anchored to the literature. I am also grateful to teaching assistant Stijn Salden for his practical assistance during the empirical work, particularly with the methodological and computational challenges that inevitably arise when combining gravity estimation with input-output-based emissions accounting.

Félix Zaidi

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List of Abbreviations

EU	European Union
WTO	World Trade Organization
PTA	Preferential Trade Agreement
RTA	Regional Trade Agreement
FTA	Free Trade Agreement
EPA	Economic Partnership Agreement
NAFTA	North American Free Trade Agreement
CETA	Comprehensive Economic and Trade Agreement
NAAEC	North American Agreement on Environmental Cooperation
CGE	Computable General Equilibrium
SCT	Scale-Composition-Technique (framework)
PPML	Poisson Pseudo-Maximum Likelihood
DiD	Difference-in-Differences
FE	Fixed Effects
CBAM	Carbon Border Adjustment Mechanism
CO_2	Carbon Dioxide
GHG	Greenhouse Gas
GDP	Gross Domestic Product
USD	United States Dollar
OECD	Organisation for Economic Co-operation and Development
ICIO	Inter-Country Input-Output
TiVA	Trade in Value Added

1. Introduction

1.1 Trade, sustainability, and the missing link

International trade is widely recognised as a key driver of economic growth, yet its environmental consequences remain far less visible and understood. When goods cross borders, the emissions generated during their production remain in the country of origin, while the demand for those goods may arise elsewhere. A product consumed in Europe can therefore embody emissions generated in Mexico or other trading partners, thereby separating consumption-based from production-based environmental impacts. As a result, trade policy shapes not only economic outcomes but also the geographical distribution of environmental pressures. As climate concerns move to the centre of policymaking, this raises a fundamental question: do trade agreements promote sustainable outcomes or merely shift environmental burdens across countries?

This question has become increasingly important within the European Union. Trade agreements are no longer evaluated solely on their capacity to stimulate growth, but also on their compatibility with climate objectives. Despite this shift in priorities, systematic evidence on the realised environmental effects of free trade agreements remains limited. While sustainability has become a central policy objective, the empirical tools used to assess trade agreements have not fully adapted to this new reality.

From an economic perspective, the effects of trade agreements are well understood. By reducing tariffs and non-tariff barriers, free trade agreements promote integration, encourage specialisation, and generate welfare gains. The European Union has developed one of the world's most extensive networks of such agreements, with approximately 44 agreements in force covering 76 partner countries (European Commission, 2025). These agreements have been widely analysed using structural gravity models, which have become the benchmark framework for evaluating trade policy. Within this framework, bilateral trade flows are explained by trade costs and economic size, allowing researchers to identify trade creation and trade diversion while controlling for multilateral resistance and unobserved heterogeneity.

In contrast, the environmental evaluation of trade agreements has followed a different tradition. Sustainability Impact Assessments, such as those conducted for the EU-Mexico agreement (European Commission, 2015), rely predominantly on ex ante computable general equilibrium simulations. These models provide internally consistent projections of how trade liberalisation may affect environmental outcomes. However, they derive these outcomes from imposed structural assumptions and calibrated parameters, rather than from observed post-agreement adjustments in trade patterns. As a result, they do not directly capture how firms and countries respond to changes in trade policy once an agreement enters into force.

1.2 How trade agreements affect emissions

This distinction matters because the environmental consequences of trade agreements arise through changes in trade itself. When trade barriers are reduced, countries do not simply trade more. They change what they trade and with whom they trade. These adjustments alter the geographical distribution of production and, consequently, the location and magnitude of emissions embodied in traded goods. Any empirical framework that aims to evaluate the environmental impact of trade agreements must therefore begin by identifying how trade flows respond to policy changes.

The structural gravity model provides a natural starting point for this analysis. Although it is widely used to estimate the economic effects of free trade agreements, its application to environmental outcomes remains relatively limited. The principal methodological reference for the present thesis is Aichele and Felbermayr (2015), who derived a theoretical gravity equation for the CO_2 content of bilateral trade and combined it with an input-output framework to construct embodied-emissions measures at the bilateral and sectoral level. Applied to the Kyoto Protocol, their estimations document that countries with binding commitments increased their embodied carbon imports from non-committed partners by approximately 8 per cent, providing evidence of carbon leakage. Their core contribution, namely the operationalisation of bilateral embodied emissions within a structural gravity framework, is the analytical foundation on which this thesis builds. These theoretical and methodological foundations are examined further in Chapter 2.

This insight motivates the empirical approach of this thesis. If a trade agreement changes bilateral trade flows, and if emissions are embodied in those flows, then the agreement can indirectly affect emissions through the trade channel. By combining a structural gravity model of trade with input-output-based measures of embodied CO_2 emissions, the environmental footprint of a trade agreement can be evaluated using realised data rather than simulated scenarios.

Interpreting these effects requires a clear conceptual framework. The environmental impact of trade can be decomposed into three channels. Trade liberalisation may expand overall trade volumes, raising total emissions through a scale effect. It may also shift trade toward cleaner or dirtier sectors and partners, producing a composition effect. Finally, emission intensities within sectors may evolve over time, generating a technique effect. This decomposition is well established in the literature (Antweiler, Copeland, & Taylor, 2001; Copeland, Shapiro, & Taylor, 2021).

A gravity-based approach can credibly identify the trade-driven components, namely the scale and composition effects, as it captures how trade volumes and sourcing patterns respond to policy changes. By contrast, changes in emission intensity within sectors are not directly captured by the model, as they primarily reflect technological progress and domestic environmental regulation rather than trade policy itself. As a result, the technique effect is not estimated separately but instead inferred residually after accounting for the scale and composition effects.

Finally, the analysis uses CO_2 as the primary environmental indicator. Although not exhaustive, CO_2 is the most consistently reported greenhouse gas and is strongly correlated with other industrial pollutants (Antweiler, Copeland, & Taylor, 2001). Its use is standard in the trade-environment literature and allows for meaningful cross-country and sectoral comparisons based on input-output data.

1.3 Empirical setting: the EU-Mexico Free Trade Agreement

To study these mechanisms empirically, this thesis focuses on the European Union-Mexico Free Trade Agreement, which entered into force in 2000. As the European Union's first comprehensive agreement with a Latin American partner, it represents an important step in the expansion of European trade policy. The agreement has generated substantial growth in bilateral trade and contributed to long-term economic integration. However, its environmental consequences have not been systematically assessed using an ex post econometric framework that links observed trade adjustments to changes in embodied emissions.

This thesis addresses that gap by developing a unified empirical strategy that connects trade-policy evaluation with environmental accounting. It proceeds in two steps. First, it estimates the effect of the EU-Mexico Free Trade Agreement on bilateral trade flows using a structural gravity model. In doing so, it identifies both direct bilateral trade creation and potential spillover effects on third-country trade following the agreement's entry into force in 2000. Second, it translates these estimated trade adjustments into changes in embodied carbon dioxide emissions, thereby assessing how the agreement has influenced the distribution of emissions between the European Union, Mexico, and third-country partners.

The central research question guiding this analysis is: To what extent has the EU-Mexico Free Trade Agreement influenced trade flows and the distribution of embodied CO_2 emissions between the European Union, Mexico, and third-country partners?

By answering this question, the thesis contributes to both the academic literature and policy evaluation. While the gravity-based emission decomposition has previously been applied to multilateral environmental policies such as the Kyoto Protocol (Aichele & Felbermayr, 2015), it has not been used to assess the environmental consequences of a bilateral trade agreement. This thesis extends that framework to trade policy, applying the scale-composition-technique decomposition to the EU-Mexico FTA based on realised trade data rather than simulated outcomes.

The analysis yields three principal findings. To begin with, the EU-Mexico FTA generated bilateral trade creation of 26.4 per cent and a positive third-country spillover of 21.0 per cent, with no evidence of classical trade diversion. In addition, embodied CO_2 emissions increased by 17.8 per cent along the bilateral margin, less than proportionally to trade. This gap reflects two offsetting channels: a composition effect, since the additional trade was systematically skewed toward cleaner sectors, and a technique effect, since within-sector emission intensities declined over the post-FTA period. Finally, the environmental transmission proves structurally asymmetric: scale pressure along the EU-to-Mexico direction is offset mainly through declining within-sector emission intensities, whereas along the Mexico-to-EU direction the offset operates primarily through a compositional shift toward cleaner sectors.

The remainder of the thesis is structured as follows. Chapter 2 reviews the relevant literature on CGE models, structural gravity models, trade agreements, and the scale-composition-technique framework. Chapter 3 presents the data and methodological framework. Chapter 4 reports the descriptive evidence and empirical results. Finally, Chapter 5 concludes with policy implications and directions for future research.

2. Literature Review

2.1 CGE models: functioning and limitations in environmental analysis

A substantial share of the empirical literature assessing the environmental impact of trade agreements relies on Computable General Equilibrium (CGE) models. These models offer a comprehensive representation of the global economy, in which multiple regions, sectors, and agents interact simultaneously under equilibrium conditions. Their appeal lies in their ability to simulate how policy changes, such as the implementation of a free trade agreement, propagate through production, consumption, and trade linkages across countries.

At their core, CGE models are built on microeconomic foundations. Producers maximise profits subject to technology constraints, while consumers maximise utility given their budget constraints. International trade is typically modelled using the Armington (1969) assumption, which treats goods as differentiated by country of origin. This implies that imports and domestic goods are imperfect substitutes, allowing bilateral trade flows to respond smoothly to changes in trade costs. Market clearing conditions ensure that supply equals demand in all markets, and equilibrium prices adjust endogenously to restore balance after a policy shock. Within this framework, a trade agreement is introduced as a reduction in tariffs or non-tariff barriers, after which the model computes a new equilibrium allocation of resources.

Because of this structure, CGE models are particularly suited for ex ante analysis. The European Commission's impact assessments of trade agreements (2015), for example, rely on global CGE models such as GTAP to simulate the expected economic and environmental consequences of policy changes before they occur. These simulations quantify changes in trade flows, sectoral output, and emissions based on modelled adjustments in economic activity across sectors and countries. Environmental outcomes are not directly observed but are derived from changes in production levels combined with sector-specific emission intensities.

However, the same features that make CGE models attractive also impose important limitations, especially when the objective is to identify the realised environmental effects of trade agreements. One limitation is that CGE models depend heavily on structural assumptions regarding functional forms, substitution elasticities, and production technologies. These parameters are often calibrated rather than estimated, making the results sensitive to prior assumptions instead of observed behavioural responses. Another concern relates to the Armington (1969) structure, which limits how trade can respond to policy changes because it assumes a fixed pattern of substitution across trading partners that may not reflect actual trade reallocation. A third practical limitation is that CGE models are frequently characterised as "black boxes": the underlying model structure is often sufficiently complex that it becomes difficult to trace how a given policy shock propagates through the system and which assumptions ultimately drive the results. This opacity complicates the assessment of robustness and makes it harder to identify the precise mechanisms underlying the estimated effects.

A further limitation concerns the treatment of the technique effect. CGE models generally hold emission intensities fixed at calibrated baseline values, so that environmental outcomes respond only to changes in sectoral output levels (European Commission, 2015). Technology is typically treated as exogenous, meaning that any within-sector improvement in emission intensity is not captured. As a result, CGE-based environmental assessments of trade agreements implicitly ignore one of the three channels through which trade policy can affect emissions.

More fundamentally, CGE models are designed to simulate counterfactual equilibria rather than to identify causal effects from observed data. They produce the equilibrium outcome of a model under a hypothetical scenario that did not actually occur. Even in ex post evaluations conducted by the European Commission, where realised trade and production data are available, environmental impacts continue to be quantified through CGE-based simulations. For instance, the ex post evaluation of the EU-Mexico agreement combines descriptive evidence and gravity-based analysis of trade flows with a CGE framework to estimate greenhouse gas emissions (Ecorys, 2017). As a result, emissions are not directly inferred from observed trade reallocations but are instead derived from modelled relationships between economic activity and environmental outcomes.

This reliance on model-based simulation creates a disconnect between observed trade patterns and estimated environmental effects. In particular, CGE models are not well suited to capture trade diversion and trade creation in a causal, data-driven manner, as these mechanisms are embedded within the model structure rather than identified empirically. The gravity model literature (Magee, 2008; Larch & Yotov, 2024) has shown that standard approaches to estimating these effects depend critically on controlling for unobserved country-pair characteristics and time-varying shocks. Failing to do so substantially overstates the measured trade impact of regional agreements. CGE models, which impose a structural equilibrium rather than estimating bilateral responses, are by design unable to incorporate such controls.

Taken together, these features limit the suitability of CGE models for causal ex post identification of environmental effects, motivating the alternative empirical approaches discussed in the next section.

2.2 Gravity models as an alternative approach

In the empirical trade literature, gravity models have emerged as the dominant framework for identifying trade effects from observed data. Rather than deriving trade outcomes from imposed structural assumptions, gravity specifications estimate bilateral trade responses from observed data, allowing the effects of a specific agreement to be identified ex post and the underlying mechanisms to be examined transparently.

The gravity model, originally introduced by Tinbergen (1962), captures the basic intuition that trade between two countries increases with their economic size and decreases with the costs of trading between them. In its structural formulation, the model is grounded in microeconomic theory and incorporates multilateral resistance terms that capture the relative trade barriers faced by each country (Anderson & van

Wincoop, 2003). A standard representation of the structural gravity equation can be written as:

$$X_{ij,t} = \frac{Y_{i,t} \cdot E_{j,t}}{Y_t} \cdot \left(\frac{\tau_{ij,t}}{P_{i,t} \cdot P_{j,t}} \right)^{1-\sigma} \tag{1}$$

where $X_{ij,t}$ denotes exports from country i to country j at time t, $Y_{i,t}$ represents total output of the exporter, $E_{j,t}$ total expenditure of the importer, Y_t total world output and $\tau_{ij,t}$ bilateral trade costs. The terms $P_{i,t}$ and $P_{j,t}$ capture outward and inward multilateral resistance. The parameter σ denotes the elasticity of substitution between varieties and governs the sensitivity of trade flows to changes in trade costs. Bilateral trade costs $\tau_{ij,t}$ are typically modelled as a log-linear function of observable trade frictions, with preferential trade agreements entering as the policy-relevant component:

$$\ln \tau_{ij,t} = \rho_1 \ln \mathrm{dist}_{ij} + \rho_2 \,\mathrm{contig}_{ij} + \rho_3 \,\mathrm{lang}_{ij} + \rho_4 \,\mathrm{PTA}_{ij,t} + u_{ij,t}, \tag{2}$$

where dist_{ij} is bilateral distance, contig_{ij} and lang_{ij} are indicators for shared border and common language, and $\mathrm{PTA}_{ij,t}$ is an indicator equal to one if the country pair has an active preferential trade agreement in year t. Because $\mathrm{PTA}_{ij,t}$ is the policy variable of interest, identifying its effect requires controlling for the unobserved trade-cost components captured by $u_{ij,t}$, which is achieved through the use of high-dimensional fixed effects in the empirical implementation.

The multilateral resistance terms $P_{i,t}$ and $P_{j,t}$ are general-equilibrium constructs that solve the system:

$$P_{i,t}^{1-\sigma} = \sum_j \frac{Y_{j,t}}{Y_t} \left(\frac{\tau_{ij,t}}{P_{j,t}} \right)^{1-\sigma}, \qquad P_{j,t}^{1-\sigma} = \sum_i \frac{Y_{i,t}}{Y_t} \left(\frac{\tau_{ij,t}}{P_{i,t}} \right)^{1-\sigma}, \tag{3}$$

capturing how trade between i and j depends not only on bilateral trade costs, but also on the costs each country faces with all its other trading partners. In the empirical implementation, the multilateral resistance terms are absorbed by exporter-time and importer-time fixed effects, following Anderson and van Wincoop (2003).

This framework is particularly well suited for evaluating trade agreements because it directly identifies how reductions in bilateral trade costs affect observed trade flows, and it captures both trade creation and trade diversion as empirical outcomes rather than model-generated artefacts. Unlike in CGE models, where such effects are generated by the calibrated structure, gravity models identify them by comparing observed trade flows before and after a policy change while controlling for confounding factors through fixed effects.

This empirical strength makes gravity models particularly relevant for environmental analysis. Since trade agreements reshape not only the volume but also the direction of trade, they alter where emissions occur and how much carbon is embodied in traded goods. A framework that captures these reallocations at the bilateral level therefore provides a natural basis for linking trade policy to environmental outcomes.

A key contribution to formalising the link between trade gravity and environmental outcomes is Aichele and Felbermayr (2015), who developed and empirically applied a theoretical gravity equation for the CO_2 content of bilateral trade in the context of evaluating the Kyoto Protocol. Their study identifies how binding climate commitments under Kyoto reshaped embodied emissions in international trade, and the analytical framework they introduce is the methodological foundation on which the present thesis builds. Building on a standard theoretical gravity framework extended to include fossil fuels as a factor of production and heterogeneous climate policies across countries, they show analytically that the carbon content of bilateral trade flows from exporter x to importer m can be written as:

$$E_{mx} \equiv \eta_x \cdot Q_{mx} \ , \qquad (4)$$

where Q_{mx} is the quantity of sectoral bilateral trade and $\eta_x \equiv e_x(I - B_x)^{-1}$ is the vector of embodied CO_2 intensities of the exporter. This expression is derived from input-output analysis, using the exporter's domestic input-output table B_x and the vector of direct sectoral emission coefficients e_x. The term $(I-B_x)^{-1}$ corresponds to the Leontief inverse, which captures both direct and indirect emissions along the production chain.

The key feature of η_x is that it is a purely exporter-specific, supply-side characteristic: it reflects the full upstream carbon content per unit of output produced in country x, independent of the destination of the trade flow. Substituting the structural gravity equation for Q_{mx} into expression (4) yields a gravity equation for embodied CO_2, in which bilateral carbon flows are driven by the same trade costs, market capacity, and supply capacity terms that govern trade volumes, scaled by the exporter's embodied emission intensity.

Aichele and Felbermayr (2015) operationalise this framework by estimating:

$$\ln\ E^s_{mxt} = \kappa \times DK_{mxt} + \mathrm{POL}_{mxt}\gamma + v_{mt} + v_{xt} + v^s_{mx} + \varepsilon^s_{mxt} \ , \qquad (5)$$

where E^s_{mxt} is the carbon content of sectoral imports of country m from country x at time t, and the key treatment variable is the differential Kyoto commitment $DK_{mxt} = K_{mt} - K_{xt}$, which takes the value 1 when only the importer has a binding Kyoto commitment, −1 when only the exporter does, and 0 when both have the same status. The full sets of country×year fixed effects v_{mt} and v_{xt} absorb all time-varying exporter- and importer-specific factors. The country pair-sector effect v^s_{mx} controls for all time-invariant bilateral heterogeneity at the sector level. The use of a differential treatment variable rather than a simple importer or exporter dummy is essential to the identification strategy: it exploits the asymmetry between committed and non-committed trading partners, and the structure of the data allows controlling for the non-random selection of countries into the Kyoto Protocol through these high-dimensional fixed effects rather than through external instruments.

The total coefficient κ on embodied carbon imports is decomposed into a scale effect and a technique effect, following directly from equation (4). The scale effect is estimated by replacing E^s_{mxt} with bilateral import quantities Q^s_{mxt} as the dependent variable. The technique effect is estimated by replacing E^s_{mxt} with the bilateral emission intensity η_{xt}^{s} directly. The two coefficients sum to κ by construction, which means that the framework does not separately identify the composition effect. This is a notable limitation, since the composition effect is one of the three canonical channels in the SCT framework. The present thesis addresses this by recovering the composition component explicitly from sector-level gravity estimates. The main finding is that binding Kyoto commitments increased committed countries' sectoral carbon imports from non-committed exporters by approximately 8 per cent, with roughly two thirds of this effect attributable to the scale channel and the remaining third to the technique channel. This constitutes direct empirical evidence of carbon leakage through the trade channel and demonstrates that policy-induced environmental reallocations can be identified from observed bilateral data rather than through simulation.

It is important to recognise that the Aichele and Felbermayr (2015) framework effectively involves two models operating in sequence. The first is a trade gravity model that identifies how a policy shock shifts bilateral trade volumes, estimated with three-way fixed effects to control for multilateral resistance, importer demand conditions, and time-invariant bilateral heterogeneity:

$$X_{ijts} = FTA_{ijt} + \gamma_{ijs} + \gamma_{its} + \gamma_{jts} + \epsilon_{ijts} \ . \tag{6}$$

Multilateral resistance terms play a genuine role in shaping bilateral trade flows, and the three-way fixed-effects structure is theoretically grounded in the structural gravity literature. The second step links those trade flows to embodied emissions through the exporter's emission intensity:

$$E_{ijts} = X_{ijts} \times e_{its} \ . \tag{7}$$

This identity is the bridge between the two models and is what makes the SCT decomposition tractable. Aichele and Felbermayr (2015) identify scale effects through changes in trade volumes and claim to identify technique effects directly through changes in bilateral emission intensity.

Once this two-step structure is made explicit, a methodological question arises that Aichele and Felbermayr (2015) do not address directly. When the emissions equation is estimated as a single gravity regression with the same fixed effects as the trade equation, the implicit assumption is that emission intensity varies bilaterally:

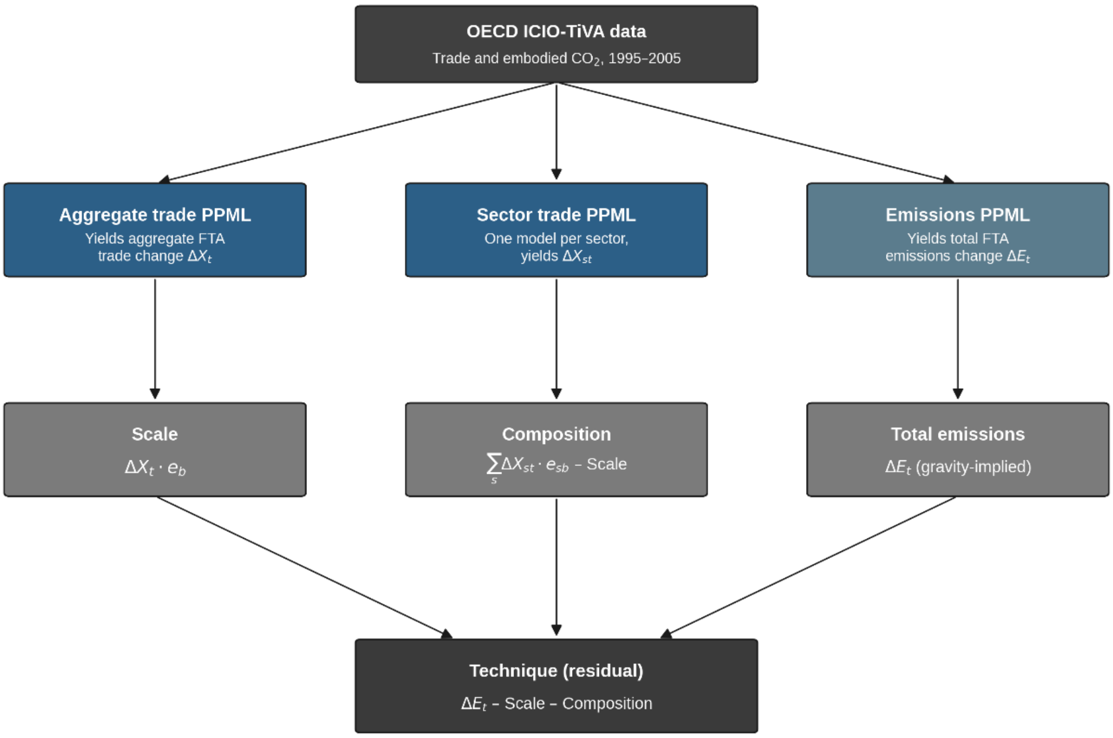
$$e_{its} = FTA_{ijt} + \gamma_{ijs} + \gamma_{its} + \gamma_{jts} + \epsilon_{ijts} \ . \tag{8}$$

This specification, however, sits uneasily with the underlying structure of emission intensities. Emission intensities are properties of the exporter's production technology rather than of the bilateral relationship: a unit of steel produced in Germany has the same carbon content whether it is exported to Mexico, Korea, or any other partner. Imposing a bilateral specification on a variable that does not vary bilaterally risks attributing variation to the wrong dimension and may produce a "technique effect" coefficient with an unclear interpretation.

This thesis therefore adopts a related but distinct strategy. Rather than estimating the technique effect from a separate gravity regression on emission intensity, the technique component is recovered residually as the total emissions change minus the scale and composition components. This residual approach respects the supply-side nature of emission intensities while preserving the bilateral structure for the scale and composition components, where such a structure is theoretically justified.

Figure 1 summarises this empirical strategy schematically. The formal definitions of the variables shown in the figure, including the gravity specifications and the construction of baseline emission intensities, follow in Chapter 3.

Figure 1: Empirical strategy linking gravity estimation to the SCT decomposition



Note: The OECD ICIO-TiVA data feed three PPML gravity regressions. The aggregate trade model yields the FTA-attributable change in total trade volumes (ΔX_t) used to compute the scale component. The sector-level trade model yields sector-specific FTA-attributable trade changes (ΔX_{st}) used to compute the composition component. The emissions model yields the total FTA-attributable change in embodied CO_2 (ΔE_t). The technique component is recovered residually as the total emissions change minus the scale and composition components. Baseline emission intensities e_β (aggregate) and $e_{s\beta}$ (sectoral) are computed from the 1995 reference year.

2.3 Environmental effects of trade agreements: EU-Mexico FTA

The literature on the environmental effects of trade agreements is still far less developed than the literature on their economic effects. This imbalance is particularly evident in the case of the EU-Mexico Free Trade Agreement. Mexico was the first Latin American country with which the European Union concluded an Economic Partnership, Political Coordination and Cooperation Agreement, commonly referred to as the "Global Agreement," signed in 1997. The trade pillar of the agreement entered into force in 2000 for trade in goods and in 2001 for parts of trade in services. In the years that followed, the agreement came to occupy a broader strategic role within EU trade policy. It was not only one of the earliest comprehensive EU agreements concluded outside Europe, but was also later regarded as insufficiently ambitious compared with newer-generation FTAs, which is precisely why modernisation discussions became central from 2013 onward (European Commission, 2015; Ecorys, 2017).

This background matters because the EU-Mexico agreement is not merely an incidental case. The European Commission's Impact Assessment (2015) explicitly presents the agreement as one that contributed to strong growth in bilateral trade and investment, while also arguing that the agreement no longer matched the depth and scope of more recent EU trade arrangements. The same document notes that bilateral trade in goods increased by 183 per cent in euro terms between 1999 and 2014, which reinforced the importance of the bilateral relationship but also motivated a reassessment of the agreement's long-run adequacy. In this sense, the EU-Mexico case is particularly useful for environmental analysis because it combines a long post-implementation period with a strong policy rationale for reassessment. In the empirical analysis, however, the focus is restricted to the short- to medium-term period following the agreement's entry into force. This restriction is intended to isolate the effects of the trade agreement itself and to limit the influence of later confounding shocks, such as the 2008 Global Financial Crisis, that could otherwise distort the identification of its impact.

As discussed in Section 2.1, a large share of the literature assessing the environmental impact of trade agreements relies on CGE-based simulations and related mixed-method approaches. This is also evident in the case of the EU-Mexico agreement. The European Commission's assessment (2015) of the modernisation of the agreement follows a standard ex ante approach, in which environmental outcomes are projected under alternative liberalisation scenarios rather than identified from observed data.

The conclusions of this literature are generally cautious. In the EU-Mexico case, the Commission reports that the environmental effects of the agreement are limited, with only marginal changes in resource use and emissions. While informative, such findings remain inherently tied to the assumptions of the underlying modelling framework and reflect simulated rather than realised outcomes.

A similar pattern emerges in the Ecorys (2017) ex post evaluation of the agreement, where environmental outcomes are again derived from a CGE-based extension rather than from observed embodied emissions. The findings are modest in magnitude. The report concludes that the agreement's environmental effects are indirect and mainly stem from changes in production and trade patterns rather than from explicit environmental provisions in the agreement itself. For Mexico, the estimated effects include a small decline in CO_2 emissions of around 0.41 million tonnes, equivalent to about 0.10 per cent, while the EU records a small increase of approximately 0.56 million tonnes, around 0.01 per cent of EU CO_2 emissions. The report also finds very small changes in air pollutants, including a reduction in sulphur oxides in Mexico of about 0.28 per cent, while other pollutant changes remain close to zero. These results reinforce the conclusion that, in the existing policy literature, the environmental effects of the EU-Mexico FTA are generally assessed as quantitatively limited.

At the same time, these “small effects” should be interpreted carefully. The same Ecorys (2017) study notes that the agreement affects both the scale of economic activity and the composition of the economy, and that these channels partly offset one another. It also acknowledges that indirect effects related to technology improvements or changes in preferences toward abatement are not fully taken into account. This is important because it means that the apparently small aggregate effects may still conceal meaningful reallocations across sectors and countries. In other words, the literature often concludes that the overall environmental effect is limited, but is less able to determine whether the agreement has shifted embodied emissions between Mexico and the European Union.

This problem is not unique to the EU-Mexico agreement. The broader literature on the environmental effects of specific trade agreements remains fragmented and method-dependent. The NAFTA case, which overlaps temporally with the EU-Mexico sample period and shares Mexico as a partner country, illustrates this pattern clearly. Unlike the EU-Mexico agreement, NAFTA was accompanied by an explicit environmental side-agreement, the North American Agreement on Environmental Cooperation (NAAEC), and by the creation of the Commission for Environmental Cooperation to monitor and coordinate trilateral environmental outcomes (Gladstone, Liverman, Sanchez Rodríguez, & Morales Santos, 2021). Despite this more ambitious environmental architecture, the empirical literature on NAFTA’s environmental effects has produced mixed and often contradictory findings. Grossman and Krueger (1991), in a seminal pre-NAFTA assessment, combined simulated output effects with U.S. pollution data and projected modest but sector-specific pollution increases concentrated in chemicals and base metals. Reinert and Roland-Holst (2001), using a multi-country applied general equilibrium model with fourteen pollutants, reached broadly similar conclusions.

Subsequent ex post analyses remain inconclusive. For instance, Logsdon and Husted (2000) find that while environmental policy and regulatory frameworks in Mexico strengthened following NAFTA, the evidence on actual environmental quality outcomes remains mixed and difficult to attribute directly to the agreement. Taken together, these studies suggest that even agreements containing dedicated environmental provisions do not necessarily produce clear-cut environmental outcomes when assessed ex post using heterogeneous methodologies. This mirrors the fragmentation observed in the EU-Mexico literature and reinforces the value of a unified, observation-based empirical framework for tracing how trade agreements affect embodied emissions through actual sourcing changes.

This is precisely where the remaining gap in the literature becomes visible. The current evidence identifies the EU-Mexico FTA as an economically meaningful agreement with relatively modest environmental effects in aggregate, but those conclusions rely predominantly on CGE-based impact assessment, mixed-method ex post evaluation, and qualitative interpretation. What is still largely missing is an ex post econometric assessment that directly links observed trade creation and trade diversion under the agreement to changes in embodied CO_2 across sectors and partners. Existing studies also tend to pay insufficient attention to partner-specific reallocation, even though the location of production is central when countries differ in emission intensity.

2.4 The scale-composition-technique framework

Having established that the existing literature on trade agreements relies heavily on model-based environmental assessment and provides limited ex post evidence on realised emissions reallocation, a more precise conceptual framework is needed to interpret how trade liberalisation translates into environmental outcomes. In this thesis, that role is fulfilled by the scale-composition-technique framework. Originally associated with the work of Grossman and Krueger (1991) and later formalised by Antweiler, Copeland, and Taylor (2001), this framework remains the standard analytical lens for decomposing the environmental consequences of economic integration. Its value lies in showing that trade does not affect emissions through a single channel. Instead, liberalisation changes the overall level of economic activity, the allocation of production across sectors and locations, and, potentially, the emission intensity of production itself. The net environmental effect of a trade agreement therefore cannot be inferred a priori, but must be established empirically.

The first channel is the scale effect. When trade barriers fall, firms gain improved market access, bilateral trade expands, and production rises along the margins most affected by the agreement. If the sectoral structure of production and the technologies used remain unchanged, this increase in economic activity leads mechanically to higher energy use and higher emissions. In empirical work, this channel is generally associated with changes in trade values or trade volumes. For the purposes of this thesis, the scale effect is expected to be particularly relevant for trade between the EU and Mexico, as the FTA reduces trade costs and increases bilateral trade between the two partners. This expansion in trade leads to higher levels of economic activity and therefore tends to increase embodied emissions, unless it is offset by other effects.

The second channel is the composition effect. Trade liberalisation alters relative prices, profitability, and specialisation incentives, which means that sectors do not expand uniformly after an agreement enters into force. Countries may specialise according to comparative advantage, factor endowments, technological capabilities, or regulatory differences, and the environmental implications of this reallocation depend on which sectors expand and which contract. If production shifts toward pollution-intensive sectors, emissions rise. If expansion occurs in cleaner sectors, emissions may fall. In the context of trade agreements, composition effects operate not only within partner countries but also across trading partners. A free trade agreement may redirect sourcing away from third countries and toward preferential partners, thereby changing not only the value of trade but also the location of emission-intensive production.

The Pollution Haven Hypothesis, originally formalised by Copeland and Taylor (1994), suggests that differences in environmental regulation may influence the location of pollution-intensive production once trade costs fall. Firms may respond to heterogeneous regulatory environments by shifting production toward jurisdictions where environmental standards are weaker, or where enforcement is less stringent, thereby changing the geographical pattern of emissions without necessarily changing final demand. Copeland, Shapiro, and Taylor (2021) argue that such adjustments do not require the relocation of entire industries. Within the SCT framework, these reallocations matter because they change the composition of production across countries and sectors.

Carbon leakage can be positioned in the same way. Whereas the Pollution Haven Hypothesis focuses on the incentive to relocate pollution-intensive production toward less regulated economies, carbon leakage refers to the broader outcome in which emissions reductions in one jurisdiction are offset by increases elsewhere (Peters & Hertwich, 2008; Aichele & Felbermayr, 2015). In practice, both mechanisms reflect the same underlying logic: production, and therefore emissions, may move across borders when policy, technology, or cost conditions differ sufficiently. In this sense, carbon leakage is the aggregate manifestation of composition changes across countries linked through trade and production networks. For the environmental evaluation of trade agreements, this distinction is important because an agreement may appear to reduce territorial emissions in one country while simultaneously increasing embodied emissions elsewhere.

The third channel is the technique effect. Trade integration can influence the emission intensity of production through several mechanisms. Rising incomes may increase demand for environmental quality, leading governments to strengthen environmental regulation and firms to invest in pollution control technologies. Openness may also facilitate the diffusion of cleaner technologies, managerial practices, and environmental standards through trade, foreign direct investment, and participation in global value chains. If these forces dominate, emissions per unit of output decline even as trade and production expand. In the empirical literature, technique effects are often associated with longer-run improvements in energy efficiency and pollution control. Shapiro and Walker (2018), for example, show that technique effects have played an increasingly important role in explaining emissions reductions in advanced manufacturing economies.

For empirical work, however, the technique channel is also the most difficult to isolate directly. Detailed and internationally comparable data on technology adoption, environmental practices, or within-sector emission reductions are rarely available across countries, sectors, and years in a way that permits direct identification. For that reason, technique effects are often inferred residually once the contributions of scale and composition have been accounted for. This is also the logic adopted in the present thesis. The empirical design identifies trade-related adjustments through the gravity framework and links them to embodied emissions. Once the parts attributable to changes in overall trade and changes in the allocation of trade across sectors and partners have been measured, the remaining component is interpreted as technique. This does not imply that the technique channel is unimportant. On the contrary, evidence from advanced economies suggests that technique effects can be quantitatively meaningful (Shapiro & Walker, 2018), though their magnitude in developing-country contexts is less well established.

The relevance of the SCT framework becomes even clearer once environmental outcomes are considered in value-chain terms. In modern production systems, a substantial share of emissions is embodied in intermediate and final goods that cross borders multiple times before final consumption. This makes embodied-emissions accounting essential for evaluating trade agreements, since free trade agreements often alter sourcing patterns rather than simply changing domestic production levels. Multi-country input-output frameworks, such as the OECD ICIO-TiVA database, allow emissions to be traced through global production networks and linked to changes in partner- and sector-specific trade flows (OECD, 2023; Yamano & Guilhoto, 2020).

In this respect, this framework is particularly valuable because it provides the accounting backbone needed to map policy-induced trade changes into environmental outcomes at the country-sector-partner level. It is also one of the few databases that links bilateral trade flows to corresponding bilateral embodied-emissions flows within a globally consistent input-output structure. At the same time, its use involves important limitations. Detailed bilateral data on emissions generated by international transport are not available, so embodied-emissions measures are constructed at the factory gate, capturing emissions generated up to and including the point of production but not those associated with shipping the goods to their destination. Sectoral emission intensities are similarly not bilateral by construction, but assigned at the country-sector level. Factory-gate accounting therefore provides the most detailed and consistently measured environmental data currently available for cross-country sectoral analysis. As a result, the framework offers a highly informative representation of embodied carbon in trade, while still abstracting from some margins of heterogeneity that may matter for precise bilateral environmental accounting. This also clarifies why sectoral disaggregation is indispensable in the present context. Because the composition effect operates through changes in the sectoral allocation of trade, it cannot be identified using aggregate trade values alone. Without sector-level information, it is impossible to determine whether trade expansion occurs in relatively clean or relatively pollution-intensive activities.

This embodied-emissions perspective also explains why carbon dioxide is the appropriate environmental indicator for the analysis. CO_2 is consistently reported across countries and sectors and is therefore suitable for large cross-country datasets. It is also closely correlated with other greenhouse gases generated in industrial production, which makes it a practical proxy for broader climate pressures (Lamb, 2021). In addition, CO_2 aligns directly with the current focus of trade-related climate policy, including EU climate targets and instruments such as the Carbon Border Adjustment Mechanism. Although environmental impacts clearly extend beyond carbon dioxide to local air pollution, water use, land use, and biodiversity, an embodied-CO_2 perspective offers the most tractable and policy-relevant basis for analysing the environmental effects of trade agreements in a sectoral and bilateral framework.

Taken together, the literature reviewed in this chapter identifies three gaps that the empirical strategy of this thesis is designed to address. First, environmental evaluations of EU trade agreements remain dominated by ex ante CGE simulations, leaving observed post-implementation outcomes largely unexamined. Second, the existing literature on the EU-Mexico FTA does not provide an econometric assessment that links trade reallocation directly to embodied emissions using a unified empirical framework. Third, the SCT framework has rarely been applied alongside structural gravity estimation on observed bilateral data, even though such an integration is necessary to identify the channels through which trade liberalisation translates into environmental outcomes. The research question formulated in Section 1.3 is structured around these three gaps, and the methodology developed in Chapter 3 operationalises this strategy.

3. Methodology

3.1 Empirical framework

This thesis evaluates the economic and environmental impacts of the EU-Mexico Free Trade Agreement through an ex post empirical framework that combines structural gravity estimation with input-output-based emissions accounting. The timing, scope, and policy context of the agreement are described in Section 2.3.

The economic logic underpinning the analysis is straightforward. A free trade agreement functions as a policy-induced reduction in bilateral trade costs between participating countries, modifying the relative prices faced by firms and consumers and thereby triggering adjustments in international trade patterns. These adjustments operate along two distinct margins: trade creation along the preferential bilateral relationship, and trade diversion or expansion at the external margin, where third-country exporters either lose or gain share in the preferential markets. Both margins are environmentally consequential because the carbon intensity of production differs across trading partners, so changes in sourcing patterns reshape not only the volume but also the geographic distribution of emissions embodied in trade.

Because FTAs influence environmental outcomes indirectly through trade reallocation, this thesis treats emissions not as an independent behavioural outcome but as a function of observed trade adjustments. The empirical strategy proceeds in three stages. It begins by estimating the trade-flow response to the EU-Mexico FTA using a structural gravity model that separately identifies bilateral trade creation and third-country spillover effects. The analysis then estimates parallel gravity models for embodied CO_2 emissions using identical fixed effects and treatment variables, ensuring that any difference between the trade and emissions coefficients reflects genuine compositional or technological adjustments rather than specification differences. Finally, these estimated coefficients are incorporated into a scale-composition-technique decomposition that traces how the FTA's economic effects translate into environmental outcomes by separating volume changes from sectoral reallocation and within-sector intensity changes. The overall empirical strategy is summarised schematically in Figure 1 (Section 2.2).

The empirical analysis relies on four classes of variables: bilateral sectoral trade flows in current US dollars, embodied CO_2 emissions in those flows expressed in million tonnes, treatment indicators for the EU-Mexico FTA and for third-country spillover dyads interacted with a post-2000 dummy, and a time-varying control for other active preferential agreements. All variables are observed at the exporter-importer-sector-year level over the 1995-2018 sample, with the formal econometric analysis restricted to 1995-2005 to isolate the FTA effect from later confounding policy and macroeconomic developments. The full data sources and construction are described in Section 3.2.

The empirical strategy focuses on emissions embodied in exports rather than emissions associated with domestic consumption. FTAs primarily affect where goods are produced and sourced rather than overall consumption levels, so production-based embodied emissions, defined as the emissions generated in the production of exported goods and attributed to the exporting country, provide a direct mapping between trade reallocation and environmental outcomes at the point of production.

The analysis is implemented using Poisson Pseudo-Maximum Likelihood (PPML) estimation combined with high-dimensional fixed effects. PPML is well-suited to bilateral trade and emissions data because it provides consistent estimates in the presence of heteroskedasticity and naturally accommodates zero observations, both of which are pervasive in disaggregated trade flows. The estimation includes high-dimensional fixed effects absorbing multilateral resistance terms, time-varying supply and demand conditions, and all time-invariant bilateral characteristics. This fixed-effects structure isolates the FTA-attributable component of trade and emissions adjustments from broader global trends and structural bilateral heterogeneity. The full econometric specifications are presented in Section 3.4, while Section 3.5 details the scale-composition-technique decomposition procedure.

3.2 Data

This section describes the data sources, coverage, variable construction, and preprocessing steps used to operationalise the empirical framework outlined in Section 3.1. The objective is to ensure transparency and replicability.

The empirical analysis draws on the OECD Inter-Country Input-Output (ICIO) tables and the OECD Trade in Value Added (TiVA) indicators (2023 edition). These databases provide a consistent mapping between bilateral trade flows, sectoral production structures, and associated CO_2 emissions across countries and over time. The ICIO-TiVA framework is particularly suited to this study because it allows emissions to be traced along global value chains and attributed to traded goods rather than to territorial production alone. The 2023 edition covers 76 economies plus a rest-of-the-world aggregate from 1995 to 2018, including all EU member states, Mexico, and a broad set of third-country trading partners.

The analytical sample spans 1995 to 2005, providing five pre-treatment years (1995-1999) and six post-treatment years (2000-2005) around the FTA's entry into force in 2000. The end-year 2005 is a deliberate identification choice rather than a data constraint. Extending the sample beyond this window would introduce confounding factors such as the proliferation of new trade agreements and structural transformations in global value chains, making it more difficult to isolate the causal effect of the EU-Mexico agreement from broader global trends. The modernised EU-Mexico agreement concluded in 2018 is not evaluated here, as the OECD ICIO-TiVA data extend only to 2018 and leave no meaningful post-treatment period to assess its effects.

EU membership is treated as a time-varying characteristic, with each country coded as an EU member in year t if it had acceded by that year. This approach avoids the misclassification of pre-accession trade flows and ensures correct treatment assignment throughout the sample. The 2004 EU enlargement is reflected accordingly, and all EU member states including the United Kingdom are correctly coded as EU members throughout the analytical sample. The EU-Mexico FTA is coded as entering into force in 2000, with a post-treatment indicator equal to one for all years $t \geq 2000$ and zero otherwise.

The dataset is structured at the exporter-importer-sector-year level. Each observation corresponds to exports from country i to country j in sector s in year t. This high-dimensional structure serves three main purposes. First, it captures sectoral heterogeneity in both trade responses and carbon intensities, allowing the analysis to account for differences in emissions across industries. Second, it enables the identification of spillover effects involving third-country exporters by providing the bilateral and sectoral granularity needed to distinguish flows from third countries into the European Union or Mexico from flows between unaffected country pairs. This distinction is central to the environmental evaluation of the agreement and is operationalised through the econometric specification described in Section 3.4. Third, the country-sector structure aligns naturally with input-output-based embodied-emissions accounting, which is likewise defined at the country-sector level. Domestic trade flows are retained in the dataset as part of the comparison group, but are excluded from all treatment definitions, so identification of FTA effects relies exclusively on variation in international trade relationships.

The empirical analysis examines two outcome variables. One concerns bilateral trade flows, which measure the nominal export value from exporter i to importer j in sector s and year t, expressed in current USD. As is typical for highly disaggregated bilateral trade data, the distribution of trade flows is strongly skewed, with many zero or small flows and a long right tail. The second is embodied CO_2 emissions in exports, which capture the total CO_2 emissions embodied in exports from exporter i to importer j in sector s and year t, including emissions generated at all upstream production stages. The measure is expressed in million tonnes of CO_2 and is constructed from sector-level emission intensities combined with input-output linkages provided in the OECD ICIO-TiVA environmental extensions, so it captures the embodied carbon footprint of traded goods regardless of the country in which the emissions physically occur. Both outcome variables are non-negative and contain a substantial number of zero observations, which has important implications for the choice of econometric estimator (Section 3.4).

The sectoral dimension of the dataset is central to the empirical framework. The OECD ICIO database distinguishes production across industries with markedly different technologies and carbon intensities, allowing the analysis to capture how changes in the sectoral composition of trade affect embodied emissions. This is essential for identifying composition effects within the SCT decomposition, as sector-level data enable a clear separation from scale and technique components. A complete overview of the sector classification is provided in Appendix A.1.

For descriptive analysis and treatment definitions, bilateral flows are classified into four groups: EU-Mexico, EU-third countries, Mexico-third countries, and other international flows. Each observation is assigned to exactly one group through a hierarchical rule that prioritises the EU-Mexico relationship, followed by EU-third and Mexico-third flows, with all remaining observations classified as "Other". These groupings are constructed over the full 1995-2018 sample and underpin both the descriptive comparisons in Chapter 4 and the formal treatment definitions introduced in Section 3.3.

An additional policy-related control captures the presence of preferential trade agreements other than the EU-Mexico FTA. The variable is constructed from the WTO Regional Trade Agreements database and is time-varying, taking the value one in year t if any preferential agreement other than the EU-Mexico FTA is active between countries i and j, and zero otherwise. Standard gravity controls such as GDP, distance, and other bilateral characteristics are not included explicitly, as they are absorbed by the high-dimensional fixed-effects structure introduced in Section 3.4.

Prior to estimation, country identifiers are harmonised using ISO3 codes and sector classifications are standardised according to the OECD ICIO industry framework. Observations with missing or negative trade or emissions values are excluded, while zero-valued observations are retained in accordance with the PPML estimation strategy. Aggregate annual trade and emissions totals are also inspected to verify the internal consistency and broad global coverage of the dataset.

Table 1 summarises all variables used in the empirical analysis, including the two outcome variables, the policy-related control PTA, the post-treatment indicator, the treatment dummies EU-MEX and Spillover that formalise the descriptive groupings introduced above, and the baseline sectoral emission intensity that enters the SCT decomposition.

Table 1: Variables and data sources

Variable	Description	Unit	Source
X_{ijst}	Bilateral export value, exporter i to importer j, sector s, year t	Current USD	OECD ICIO, 2023 edition
C_{ijst}	Embodied CO_2 emissions in exports, exporter i to importer j, sector s, year t	Million tonnes CO_2	OECD TiVA, 2023 edition (environmental extension)
$Post_t$	Indicator equal to one for $t \geq 2000$	0/1	Constructed
$EU - MEX_{ij}$	Indicator for bilateral trade flows between EU member states and Mexico	0/1	Constructed using time-varying EU membership
$Spillover_{ij}$	Indicator for third-country exporter shipping to EU or Mexico	0/1	Constructed
PTA_{ijt}	Indicator for active preferential trade agreement between i and j in year t, excluding the EU-Mexico pair	0/1	WTO Regional Trade Agreements database
e_{sb}	Sector s baseline emission intensity	CO_2 per unit of exports	Constructed from OECD ICIO-TiVA, 1995 reference year

3.3 Identification strategy

This section explains how the empirical framework identifies the effects of the EU-Mexico Free Trade Agreement on trade flows and embodied CO_2 emissions. The identification strategy follows a difference-in-differences logic embedded in a structural gravity panel, exploiting variation across country pairs, sectors, and time.

The EU-Mexico FTA entered into force in 2000 and provides a discrete policy shock. Identification relies on comparing changes in outcomes before and after 2000 for country pairs affected by the agreement, relative to appropriate control pairs that were not directly exposed. The analytical sample spans 1995 to 2005, providing five pre-treatment years (1995-1999) and six post-treatment years (2000-2005) around the agreement's entry into force, as discussed in Section 3.2.

The empirical strategy combines time, cross-sectional, and sectoral variation through the high-dimensional fixed-effects structure detailed in Section 3.4, which absorbs multilateral resistance terms, time-varying country-sector heterogeneity, and all time-invariant bilateral characteristics. This ensures that the estimated effects reflect deviations in the trajectories of treated pairs relative to comparable untreated pairs.

3.3.1 Treated and comparison margins

The identification strategy targets two distinct policy-relevant channels: trade creation along the bilateral EU-Mexico margin, and reallocation of third-country exports toward EU and Mexican markets, which is the empirical counterpart to potential trade diversion. Trade creation is identified through changes in bilateral trade between EU member states and Mexico following the reduction in trade costs induced by the agreement. These EU-Mexico country pairs form the treated group, captured empirically by an interaction between a post-2000 indicator and an EU-Mexico pair dummy.

Potential trade diversion (or third-country spillover) is identified by examining how exports from third countries to the European Union or to Mexico evolve after 2000 relative to other international flows that are not directly affected by the agreement. This captures whether the agreement altered sourcing patterns toward the preferential partner. In the empirical specification, this mechanism is represented by a post-treatment interaction for third-country exporters supplying the EU or Mexico, complemented by a time-varying control for other preferential trade agreements to account for concurrent policy changes. Considering both margins within a single framework ensures that bilateral trade growth is not conflated with broader reallocations in global sourcing patterns, which is particularly important for assessing where production-related emissions occur.

3.3.2 Addressing potential threats to identification and scope limitations

Several potential threats to causal interpretation are considered explicitly within the empirical design.

Overlapping trade agreements

Countries may enter into additional preferential trade agreements during the sample period. Such overlapping liberalisation could confound the estimated effects of the EU-Mexico FTA. To mitigate this concern, the empirical specification includes a time-varying control for all active preferential trade agreements in the sample, covering EU-third, Mexico-third, and third-third pairs. This control captures the average effect of other active PTAs across the sample period, ensuring that the EU-Mexico FTA coefficients are not confounded by concurrent liberalisation. Appendix A.4 reports an alternative specification with a post-treatment interaction on this control, confirming that the EU-Mexico results are robust to this modelling choice.

Global shocks and concurrent policies
Major global events such as financial crises, shifts in energy markets, or changes in climate policy could affect trade and emissions across many pairs simultaneously. The high-dimensional exporter-sector-year and importer-sector-year fixed effects absorb such shocks to the extent that they operate through country- and sector-specific channels. A related concern is that broad globalisation trends, namely the secular rise in the share of cross-border trade in total trade, could affect international flows differently from internal ones. In the structural gravity literature this is sometimes addressed by including a border dummy that distinguishes international from intra-national trade flows (Yotov, Piermartini, Monteiro, & Larch, 2016). The present specification does not include such a dummy because internal flows, while retained in the dataset as part of the comparison group, are excluded from all treatment definitions. Globalisation effects that operate symmetrically across exporters or importers are absorbed by the exporter-sector-year and importer-sector-year fixed effects. This thesis acknowledges, however, that residual globalisation effects that operate differentially across country pairs may not be fully absorbed by this fixed-effects structure.

Anticipation effects
Firms may adjust their trade patterns prior to formal FTA implementation if they anticipate upcoming tariff reductions. The post-treatment indicator used in this thesis captures average realised effects over the post-2000 period rather than short-lived responses to policy announcements, which limits the sensitivity of the estimates to short-run anticipation behaviour. Any persistent anticipation that began well before 2000 would be absorbed by the pair-sector fixed effects to the extent that it altered the average bilateral trade level, and would otherwise bias the estimated post-FTA coefficient downward rather than overstate it.

Scope of the third-country channel
The spillover variable captures whether third-country exports to the EU and Mexico moved differently from other international flows after 2000, but it does so by pooling all third-country exporters into a single indicator. In practice, the underlying mechanisms are heterogeneous: demand-pull spillovers, complementarity through global value chains, sector-specific tariff escalation, partner-specific regulatory environments, and residual third-country PTA effects not fully absorbed by the other-PTA control can all contribute to the observed coefficient. The present specification does not separately identify these channels, and the spillover estimate should be read as the net aggregate response of third-country supply rather than as a structural decomposition of its sources. Section 5.4 discusses extensions that could disaggregate the spillover channel further.

Within this framework, the coefficient on the EU-Mexico interaction captures the change in bilateral EU-Mexico trade flows following the entry into force of the agreement, conditional on the full set of fixed effects and controls. Economically, this coefficient reflects the extent of trade creation along the preferential bilateral margin. The spillover coefficient captures the corresponding effect on exports from third countries to either the EU or Mexico after the agreement entered into force. A negative coefficient is consistent with trade diversion away from third-country suppliers, while a positive coefficient suggests broader trade expansion and increased import demand.

When the same specification is estimated using embodied CO_2 emissions as the dependent variable, the coefficients measure how the emissions associated with these trade flows change following the agreement. The analysis therefore links observed changes in trade patterns directly to environmental outcomes. Rather than assuming that trade diversion is negligible, the empirical design treats diversion as an empirical question and estimates both its economic magnitude and environmental implications directly from the data.

3.4 Econometric specifications

This section translates the identification strategy into estimable equations. The specifications are designed to (i) identify trade creation and trade diversion within a structural gravity framework and (ii) map these effects consistently into embodied CO_2 emissions. All models are estimated on exporter-importer-sector-year data.

3.4.1 Baseline gravity specification for trade flows and embodied CO_2 emissions

Let X_{ijst} denote the value of exports from exporter i to importer j in sector s and year t. The baseline specification for trade flows is:

$$X_{ijst} = exp(\beta_1 \cdot Post_t \times EU-MEX_{ij} + \beta_2 \cdot Post_t \times Spillover_{ij} + \beta_3 \cdot PTA_{ijt} + \alpha_{ist} + \gamma_{jst} + \delta_{ijs}) \cdot \varepsilon_{ijst} \,. \quad (9)$$

Interpretation of regressors

The variable $Post_t$ is an indicator equal to one for all years $t \geq 2000$ and zero otherwise. The variable $EU\text{-}MEX_{ij}$ is an indicator for bilateral trade flows between European Union member states and Mexico (in either direction). When interacted with $Post_t$ it captures bilateral trade creation. The variable $Spillover_{ij}$ is an indicator for dyads in which a third-country exporter ships to the EU or to Mexico, and when interacted with $Post_t$ it captures spillover effects on third-country supply, which are the empirical counterpart to potential trade diversion. Note that this indicator is unidirectional: it captures flows from third-country exporters into the EU or Mexico, and does not include flows in the opposite direction. This reflects the focus on trade diversion as a supply-side reallocation toward preferential partners. Finally, PTA_{ijt} is a time-varying control that equals one in years when country pair i,j has an active preferential trade agreement, excluding the EU-Mexico treated pair.

Fixed effects

The term α_{ist} represents exporter-sector-year fixed effects and controls for time-varying supply conditions in the exporting country and sector, including technology, regulation, and macroeconomic shocks. The term γ_{jst} denotes importer-sector-year fixed effects and captures time-varying demand conditions and sector-specific shocks in the importing country. The term δ_{ijs} denotes exporter-importer-sector fixed effects and absorbs all time-invariant bilateral frictions, such as distance, common language, historical ties, and persistent sector-specific trade costs.

Taken together, this fixed-effects structure absorbs multilateral resistance terms and all time-invariant bilateral trade costs. Identification of β_1-β_3 therefore comes from changes over time within exporter-importer-sector relationships, comparing treated and untreated flows before and after the implementation of the FTA (Yotov, Piermartini, Monteiro, & Larch, 2016).

Let C_{ijst} denote embodied CO_2 emissions (million tonnes of CO_2) in exports from i to j in sector s and year t. The emissions specification mirrors the trade equation:

$$C_{ijst} = \exp(\theta_1 \cdot \text{Post}_t \times \text{EU}-\text{MEX}_{ij} + \theta_2 \cdot \text{Post}_t \times \text{Spillover}_{ij} + \theta_3 \cdot \text{PTA}_{ijt} + \alpha_{ist} + \gamma_{jst} + \delta_{ijs}) \cdot \nu_{ijst}\,. \quad (10)$$

Using the same treatment variables and fixed effects ensures that differences between the trade and emissions coefficients reflect changes in sectoral composition and emission intensities, rather than differences in identification or specification.

Both equations are estimated using Poisson Pseudo-Maximum Likelihood (PPML). This estimator is chosen for several reasons. First, trade and emissions data contain many zero observations, and PPML naturally accommodates zero outcomes without requiring logarithmic transformations of the dependent variables. Second, PPML remains consistent under general forms of heteroskedasticity, which are characteristic of disaggregated trade data. Third, for dummy regressors such as $Post_t \times EU\text{-}MEX_{ij}$ and $Post_t \times Spillover_{ij}$, the transformation $100 \times (\exp(\beta) - 1)$ yields the estimated percentage change in the expected outcome. Finally, PPML has become the benchmark estimator in modern structural gravity applications, for example, Santos Silva & Tenreyro (2006).

Standard errors are computed using two-way clustering at the exporter-importer-sector and year levels. This procedure allows for arbitrary serial correlation within dyads over time as well as for common shocks across dyads within a given year.

3.4.2 Mapping coefficients to economic and environmental mechanisms

Within this framework, the coefficients β_1 (equation 9) and θ_1 (equation 10) capture the effect of the EU-Mexico FTA on bilateral trade flows and embodied CO_2 emissions after 2000, relative to comparable country pairs. Economically, these coefficients measure the extent of trade creation generated by the agreement and the associated environmental adjustment along the EU-Mexico trade margin. The coefficients β_2 and θ_2 capture the corresponding effects for exports from third countries to either the EU or Mexico following the agreement's entry into force. Depending on their sign and magnitude, these effects may reflect either trade diversion away from third-country suppliers or broader demand-driven trade expansion. Finally, β_3 and θ_3 control for the average effect of other active preferential trade agreements during the sample period, ensuring that the estimated EU-Mexico FTA effects are not confounded by concurrent trade liberalisation elsewhere.

Comparing the estimated trade and emissions coefficients provides an initial indication of how changes in trade volumes translate into environmental outcomes. If $\theta_1 < \beta_1$, embodied emissions associated with EU-Mexico trade increased less than proportionally to trade flows, which is consistent with cleaner sectoral composition or improvements in production techniques. Conversely, if $\theta_1 > \beta_1$, emissions increased more than proportionally to trade, suggesting a shift toward more carbon-intensive trade patterns or worsening emission intensities.

3.5 Decomposition procedure

This section explains how changes in embodied CO_2 emissions are decomposed into scale, composition, and technique components. The procedure follows the logic of the scale-composition-technique (SCT) framework discussed in 2.4 and is implemented using FTA-attributable changes derived from the gravity model estimates. Specifically, the decomposition relies on model-implied counterfactual predictions that compare predicted outcomes with and without the EU-Mexico FTA while retaining the observed sectoral structure of the data.

3.5.1 Conceptual basis

Let total embodied CO_2 emissions in exports from exporter i to importer j in year t be written as:

$$E_{ijt} = \Sigma_s X_{ijst} \cdot e_{ijst}, \quad (11)$$

where X_{ijst} is the value of exports from i to j in sector s in year t, and e_{ijst} is the sector-specific CO_2 emission intensity, that is, CO_2 per unit of exports, as implied by observed embodied emissions and trade values.

Within this framework, total emissions can change through three channels. One source of variation is a change in total export volume X_{ijt}, which constitutes the scale effect. Emissions may also change when the sectoral structure of exports shifts across sectors s, which constitutes the composition effect. In addition, emission intensity within sectors, e_{ijst}, may evolve over time, producing a technique effect.

The decomposition isolates each of these channels by sequentially holding the remaining components fixed, as commonly used in the trade-environment literature (Aichele & Felbermayr, 2015; Antweiler, Copeland, & Taylor, 2001; Grossman & Krueger, 1991).

3.5.2 Baseline (reference) period

A common baseline year is defined for the decomposition. In the empirical implementation, the year 1995 is used as the reference period for all observations. This year corresponds to the first year of the sample and provides a consistent benchmark against which subsequent changes in trade and emissions can be evaluated.

Using this base year, sector-specific emission intensities are constructed from the observed trade and embodied-emissions data. For each sector s, baseline embodied emissions E_s^b and baseline export values X_s^b are aggregated across observations in the base year. Baseline emission intensities are then computed as:

$$e_s^b = \frac{E_s^b}{X_s^b}, \tag{12}$$

where e_s^b represents the amount of embodied CO_2 per unit of exports in sector s in the base year.

These baseline sectoral emission intensities are subsequently held fixed when implementing the scale-composition-technique decomposition. Holding baseline intensities constant ensures that changes in total embodied emissions over time can be attributed to changes in total trade volumes (scale effects), shifts in the sectoral composition of trade (composition effects), and changes in emission intensities (technique effects).

Using a common reference year across sectors ensures that all decomposition results are defined relative to a consistent initial production and emissions structure.

3.5.3 Scale component

The scale effect measures the change in embodied CO_2 emissions that would arise from changes in total trade volumes while holding the sectoral structure of trade and emission intensities fixed at baseline levels.

Let ΔX_t denote the change in total exports attributable to the EU-Mexico FTA in year t, as implied by the gravity model estimates. Let e^b denote the baseline emission intensity computed from the reference year. The scale component is then defined as:

$$Scale_t = \Delta X_t \cdot e_b . \tag{13}$$

This term represents the change in emissions that would occur if total trade volumes changed while both the sectoral composition of trade and sector-specific emission intensities remained fixed at their baseline levels.

3.5.4 Scale + composition component

The scale + composition component allows the sectoral structure of trade to vary over time while keeping emission intensities fixed at their baseline levels.

Let ΔX_{st} denote the FTA-attributable change in exports for sector s in year t, as implied by the gravity model estimates. Let e_s^b denote the baseline emission intensity of sector s. The scale-composition counterfactual emissions are defined as:

$$SC_t = \sum_s \Delta X_{st} \cdot e_{sb} . \tag{14}$$

The composition effect is obtained as the difference between the scale + composition component and the pure scale component:

$$Composition_t = SC_t - Scale_t \ . \qquad (15)$$

This component therefore captures the contribution of shifts in the sectoral structure of trade toward sectors that are more or less emission intensive at baseline.

3.5.5 Actual emissions and the technique effect

Let ΔE_t denote the total change in embodied CO_2 emissions attributable to the EU-Mexico FTA in year t, as implied by the gravity model estimates. The technique effect is obtained as the residual difference between the total emissions change and the scale-composition counterfactual:

$$Technique_t = \Delta E_t - SC_t \ . \qquad (16)$$

A negative (positive) value of this residual indicates a decline (increase) in emission intensities within sectors relative to baseline levels. The technique effect therefore captures changes in production technologies, energy mixes, and other factors affecting within-sector emission intensity that are not explained by changes in total trade volumes or sectoral composition. Because consistent measures of sector-level emission intensity changes are not directly observable across countries and sectors, this residual approach is the standard route to identifying the technique component in the trade-environment literature (Copeland, Shapiro, & Taylor, 2021).

3.5.6 Implementation details

In practice, the decomposition is implemented in three stages. The procedure begins by computing predicted outcomes with and without the FTA from the gravity models, thereby identifying the FTA-attributable change in trade and emissions for each year. Next, baseline sectoral emission intensities are calculated using 1995 as the reference year and are subsequently held fixed throughout the analysis. These baseline intensities are then combined with the FTA-attributable trade changes to construct the scale, scale-composition, and residual technique components.

The sector-level FTA-attributable trade change ΔX_{st} is obtained by estimating a separate PPML gravity equation for each sector s, using exporter-year, importer-year, and pair fixed effects. Because each sector model is restricted to a single industry, the sector dimension is absorbed by construction, and these fixed effects are equivalent to the exporter-sector-year, importer-sector-year, and pair-sector effects of the main specification. Predicted trade flows are computed twice for each sector model, once with the FTA treatment indicator set to one and once to zero, and the difference yields the sector-specific FTA effect. Sectors with insufficient observations, no treated dyads, or no pre-post variation are excluded. The minimum-observation threshold is set adaptively, equal to the maximum of ten observations and a value scaled to the size of the channel relative to the largest pooled channel. The aggregate trade change ΔX_t used in the scale component is derived analogously from a single PPML model on aggregated bilateral trade flows.

The same logic is applied to the spillover channel, defined as flows from third-country exporters into the EU or Mexico. The aggregate and sector-level deltas $\Delta X_t^{\text{spill}}$ and $\Delta X_{st}^{\text{spill}}$ are obtained from PPML estimation restricted to spillover dyads, and the total emissions change $\Delta E_t^{\text{spill}}$ from the spillover coefficient θ_2 in equation (10). Baseline intensities e_b and e_{sb} are taken from the same 1995 reference structure used for the bilateral channel, ensuring comparability. Scale, composition, and technique effects then follow from equations (13), (15), and (16), replacing the bilateral deltas with the spillover deltas.

Each pooled channel is further disaggregated into directional margins. The EU-Mexico channel is split into EU-to-Mexico and Mexico-to-EU flows, and the spillover channels are split analogously into third-country to EU and third-country to Mexico flows, enabling the decomposition to capture asymmetries in the environmental transmission of the FTA across the two sides of each bilateral relationship.

The three components will generally not evolve in parallel over time. The scale component is a linear function of aggregate trade changes weighted by a single baseline intensity, the composition component is a weighted sum of sector-specific trade deltas with sector-specific intensities, and the total emissions effect is derived from a separate PPML model on embodied CO_2. Since aggregate trade, sectoral trade, and emissions do not evolve proportionally, the three components move differently across years. This non-parallel evolution is not a limitation but a feature of the decomposition: it reveals the heterogeneous transmission channels through which the FTA affects emissions.

3.5.7 Linking decomposition to gravity results

The decomposition complements the gravity estimates in two principal ways. First, the gravity coefficients indicate whether and to what extent trade creation and spillover effects occurred following the EU-Mexico FTA. Second, the decomposition reveals through which mechanisms the resulting trade changes translate into emissions outcomes, namely through scale, composition, or technique effects.

For example, a positive gravity coefficient on the EU-Mexico treatment variable combined with a decomposition in which the scale component closely tracks the total emissions change suggests that emission growth is primarily driven by an expansion of trade volumes. By contrast, a large difference between the scale and the scale-composition components indicates that shifts in the sectoral structure of trade contribute importantly to the emissions outcome. Finally, a sizable difference between the scale-composition component and the total emissions change reflects the role of technique effects, meaning that within-sector emission intensities evolve over time.

Examining these components alongside the gravity estimates allows the analysis to assess whether the EU-Mexico FTA affects emissions primarily through increased trade volumes, through changes in the sectoral composition of trade, or through changes in emission intensities within sectors.

4. Empirical Results

4.1 Overview of the results

This chapter presents the empirical results of the thesis and evaluates how the EU-Mexico Free Trade Agreement affected trade patterns and the distribution of embodied CO_2 emissions across the European Union, Mexico, and third countries. The analysis follows the empirical strategy developed in the preceding chapters, which links changes in bilateral trade flows to environmental outcomes through embodied emissions.

The empirical results are organised around three analytical stages. The analysis begins with descriptive statistics that provide an overview of the evolution of trade flows, embodied CO_2 emissions, and emission intensity across the principal trade margins involving the European Union, Mexico, and third countries. Conducted over the full sample period, this section offers initial insights into the development of trade patterns and emissions over time. The second stage consists of structural gravity estimations that quantify the impact of the EU-Mexico FTA on bilateral trade flows and identify both trade creation and third-country spillover effects, the empirical counterpart of potential trade diversion. The final stage applies the scale-composition-technique decomposition to interpret how the observed trade adjustments translated into changes in embodied emissions. Taken together, these elements provide the empirical basis for assessing whether the agreement altered the carbon footprint embedded in international trade.

4.2 Descriptive evidence

This section presents descriptive evidence on the evolution of trade, embodied CO_2 emissions, and emission intensity across the principal trade margins over the full 1995-2018 descriptive sample. The analysis therefore extends beyond the 1995-2005 analytical window used in the econometric estimations in order to provide broader contextual insight. The figures provide an initial overview of how EU-Mexico trade developed over time relative to trade involving third countries and how these developments were mirrored in the carbon content of trade.

Figure 2: EU-Mexico gross trade over time

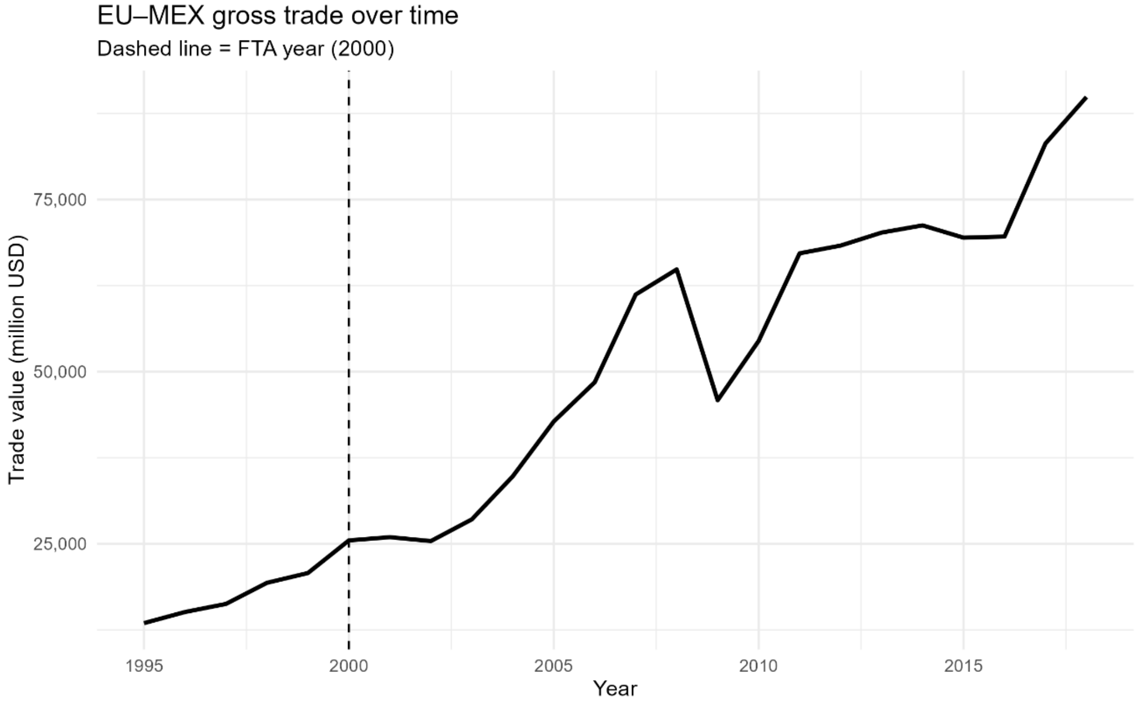


Figure 2 shows the evolution of gross bilateral trade between the European Union and Mexico over the sample period. Trade values are aggregated across all relevant observations and plotted over time, with the vertical dashed line marking the entry into force of the EU-Mexico FTA in 2000. The figure provides an initial visual overview of the treated bilateral margin that is central to the empirical analysis.

The figure displays a clear upward trend in EU-Mexico trade over the full period. Bilateral trade increases gradually during the second half of the 1990s and continues to expand after the FTA entered into force, with stronger growth during the mid-2000s and again toward the end of the sample. Although the series is not monotonic and shows a visible decline around the global financial crisis, the overall pattern is one of substantial long-run expansion in bilateral trade between the two partners.

This pattern is relevant because it indicates that the EU-Mexico relationship became progressively more important in value terms over the sample period. From the perspective of the thesis, this makes the bilateral margin an empirically meaningful setting in which to study both trade creation and the associated evolution of embodied emissions. At the same time, the figure remains descriptive and does not reveal whether the observed increase reflects the FTA itself or broader developments in world trade.

Figure 3: Relative trade growth across trade groups

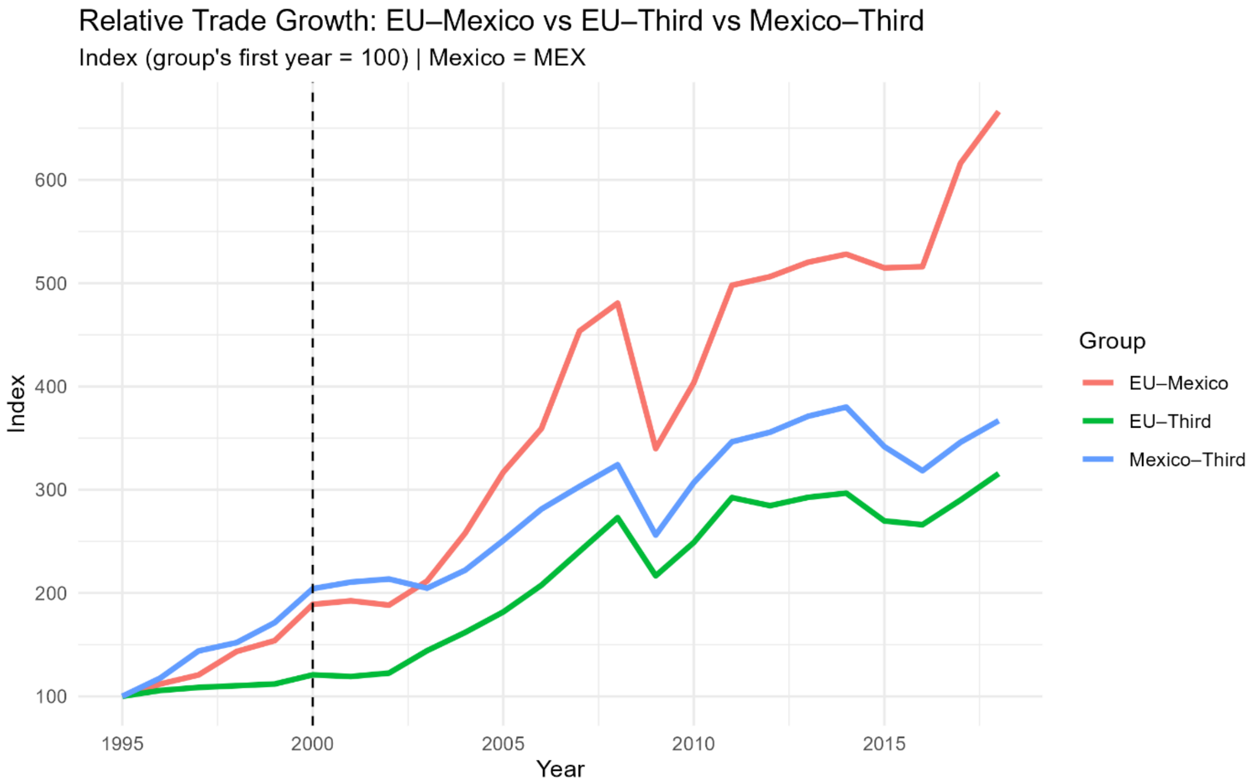


Figure 3 compares relative trade growth across three trade margins: EU-Mexico, EU-Third, and Mexico-Third. Each series is expressed as an index with the group's first observed year set equal to 100, which allows the trajectories of the three margins to be compared despite differences in their initial trade levels. The dashed vertical line again marks the year 2000.

The figure shows that trade grows across all three margins over time, but the increase is strongest for EU-Mexico trade. The indexed EU-Mexico series rises more steeply than both the EU-Third and Mexico-Third series, particularly from the early 2000s onward. Mexico-Third trade also grows substantially, while EU-Third trade follows a more moderate trajectory. Although all three series experience some fluctuations, the bilateral EU-Mexico margin displays the strongest relative expansion over the sample period.

This pattern is relevant because it provides a first visual indication that the treated bilateral margin may have evolved differently from surrounding trade relationships. The stronger relative growth of EU-Mexico trade is consistent with the possibility of trade creation, while the divergence between the three margins suggests that the agreement may also have been associated with broader reallocation effects involving third countries. At this stage, however, the figure only shows relative trends and cannot distinguish between FTA-related changes and other concurrent forces affecting international trade.

Figure 4: Relative CO_2 growth across trade groups

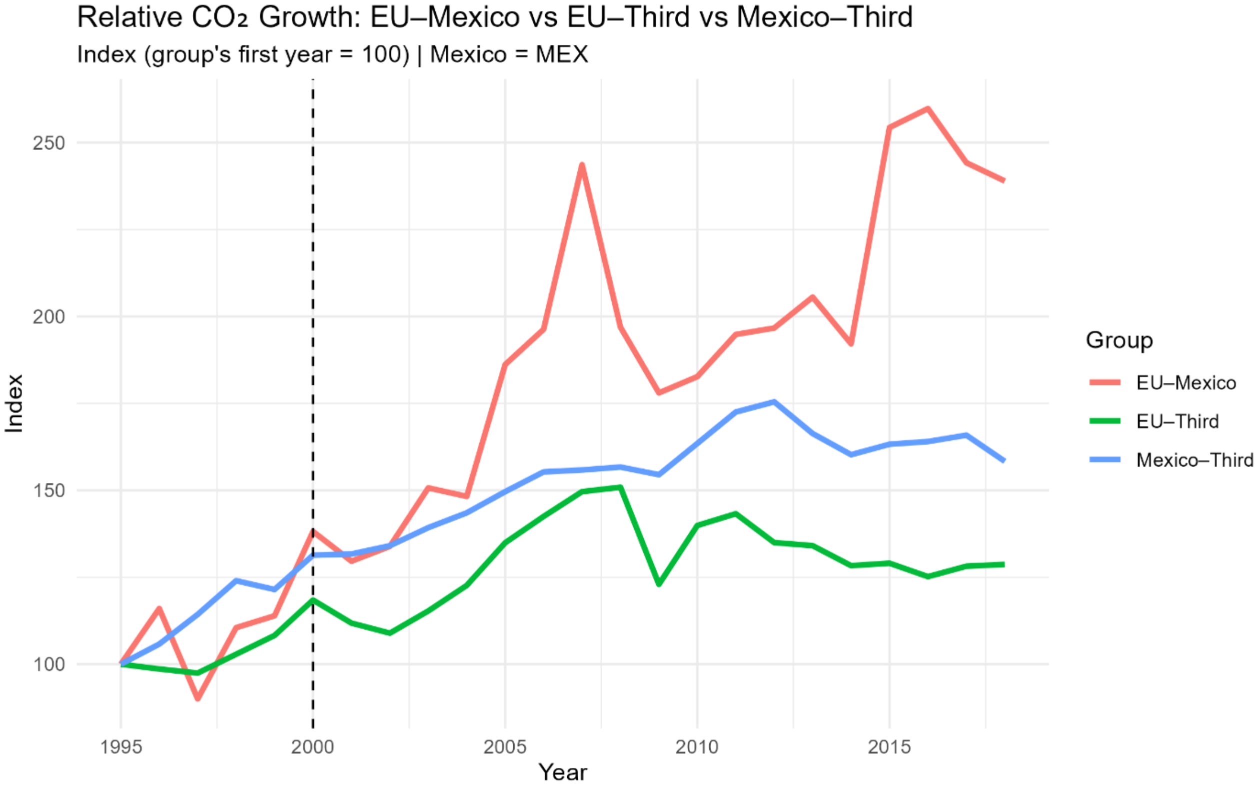


Figure 4 presents the corresponding relative growth in embodied CO_2 emissions for the same three trade margins: EU-Mexico, EU-Third, and Mexico-Third. As in the previous figure, each series is indexed to the group's first observed year, allowing the evolution of emissions to be compared across groups independently of their initial emission levels. The purpose of the figure is to examine whether the growth in trade was accompanied by similar growth in the carbon content embodied in those flows.

The figure indicates that embodied CO_2 emissions also increase over time across all three margins, but again the strongest relative increase occurs for EU-Mexico trade. The EU-Mexico series rises more sharply than the EU-Third and Mexico-Third series and remains at a higher indexed level during much of the post-2000 period. Mexico-Third emissions also increase, but less strongly, while EU-Third emissions follow the weakest trajectory of the three and remain comparatively flatter in the later years of the sample.

This pattern matters because it shows that the expansion of EU-Mexico trade was accompanied by a substantial increase in the carbon embodied in that trade. More broadly, the figure suggests that changes in trade volumes were not environmentally neutral and that the distribution of embodied emissions across trade margins also shifted over time. For the purposes of this thesis, this reinforces the importance of studying trade and embodied CO_2 jointly rather than treating them as separate domains.

Figure 5: Relative CO_2 intensity across trade groups

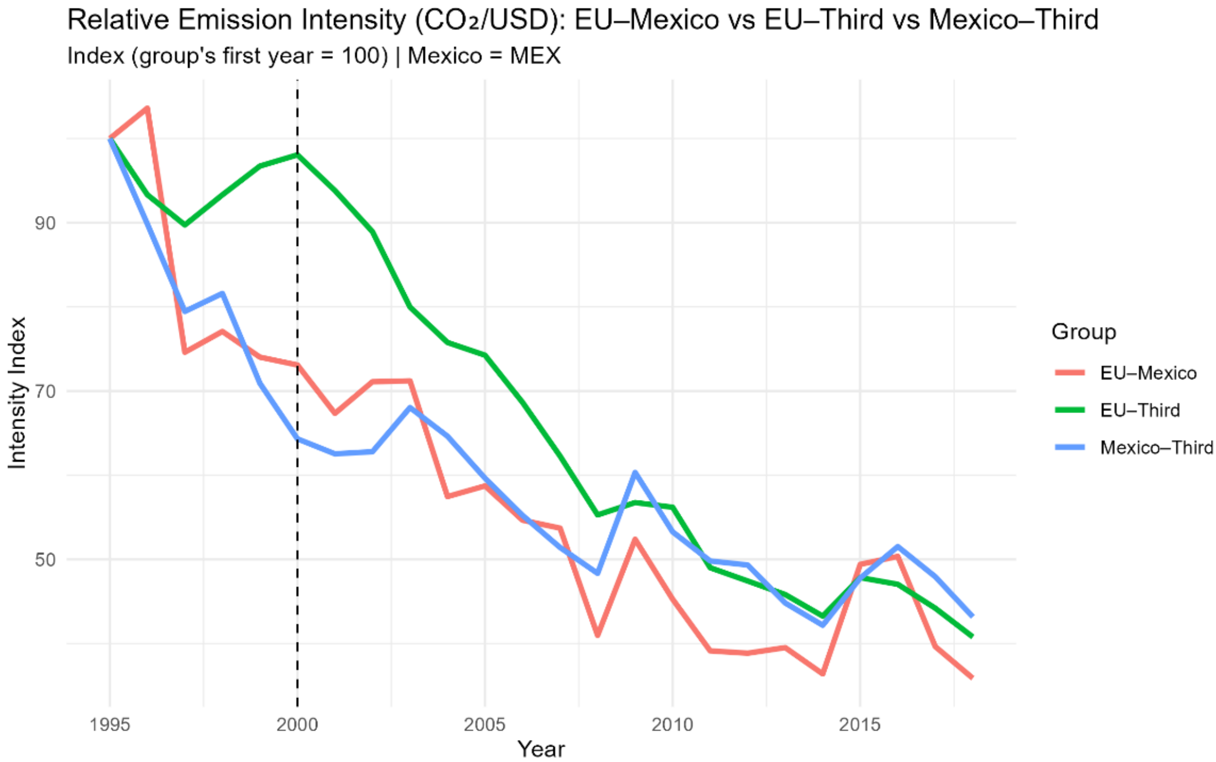


Figure 5 reports the evolution of relative emission intensity, measured as embodied CO_2 per unit of trade value, for the same three trade margins. By focusing on CO_2 per USD rather than on trade values or total embodied emissions alone, the figure provides a descriptive indication of whether the carbon content of trade became more or less intensive over time. As before, each series is indexed to the group's first observed year.

The figure shows a pronounced downward trend in emission intensity across all three margins. The decline is strongest for EU-Mexico trade, which falls more rapidly than the other two series and reaches the lowest level by the end of the sample. Mexico-Third intensity also declines substantially, while EU-Third intensity starts from a relatively high level and decreases more gradually before converging downward in the later years. Despite some short-run fluctuations, the general pattern is one of broad-based decarbonisation in the carbon intensity of trade.

This pattern is relevant because it suggests that the growth in embodied emissions shown in Figure 4 did not simply reflect a uniformly more carbon-intensive trade structure. Instead, the simultaneous increase in trade and decline in emission intensity descriptively suggest the coexistence of scale expansion and reductions in carbon intensity. In the context of this thesis, this is important because it indicates that any increase in embodied CO_2 along the EU-Mexico margin may have been moderated by cleaner sectoral composition or declining emission intensity over time.

Taken together, the descriptive evidence points to three broad patterns. First, EU-Mexico trade expanded substantially over the sample period. Second, this treated margin grew faster than the surrounding EU-Third and Mexico-Third margins. Third, embodied CO_2 emissions also increased, but against a background of declining emission intensity across all groups. These descriptive patterns are informative and provide useful intuition for the analysis that follows. They cannot, however, be interpreted causally, since many other factors may have influenced trade and emissions over the same period. The structural gravity estimations in Section 4.3 address this limitation by isolating the effect of the EU-Mexico FTA within the econometric framework developed in Chapter 3.

4.3 Gravity results: trade flows

The descriptive patterns presented in Section 4.2 indicate that EU-Mexico trade expanded substantially over the sample period and grew faster than the surrounding trade margins. While informative, these patterns cannot isolate the role of the FTA itself from concurrent developments in world trade, global demand, or other policy changes. This section addresses this limitation by presenting the results of the structural gravity estimation. These results identify the causal impact of the EU-Mexico FTA on bilateral trade flows by comparing treated and untreated country pairs before and after the agreement entered into force in 2000.

The model in equation (9) is estimated using Poisson Pseudo-Maximum Likelihood with three-way fixed effects at the exporter-sector-year, importer-sector-year, and exporter-importer-sector level. The other-PTA control enters as a level term, since the underlying WTO Regional Trade Agreements indicator is already updated annually, capturing the average effect of other active preferential agreements across the sample period. Results are presented in Table 2.

The coefficient on the direct EU-Mexico effect is 0.234 and statistically significant at the 0.1 per cent level. Applying the standard PPML transformation $\left[\left(e^{\beta}-1\right)\times 100\right]$, the estimate implies that the EU-Mexico FTA is associated with an increase in bilateral trade flows of approximately 26.4 per cent relative to the counterfactual of no agreement, after conditioning on the full set of fixed effects and controls. This constitutes economically meaningful trade creation along the treated bilateral margin and is consistent with the descriptive patterns documented in Section 4.2, while establishing that a substantial portion of the observed expansion is attributable to the agreement itself rather than to global trade trends.

The spillover coefficient is 0.191 and statistically significant at the 0.1 per cent level, implying an increase of approximately 21.0 per cent in third-country exports toward the EU or Mexico in the post-FTA period. This result stands in contrast to the classical trade diversion hypothesis, under which third-country exports would be expected to decline as preferential partners gain market access.

Several mechanisms may explain this positive spillover effect. First, the FTA may have stimulated aggregate demand in both the EU and Mexico through income effects, raising total import demand from all origins rather than substituting selectively for preferential-partner supply. This demand-pull channel is consistent with the broader evidence that EU agreements tend to generate import-expanding rather than import-displacing effects at the aggregate margin (Larch & Yotov, 2024).

Second, complementarity in global value chains may cause third-country intermediate input flows to expand alongside EU-Mexico final goods trade. If European and Mexican firms deepened their bilateral production integration after 2000, demand for upstream intermediate inputs from third-country suppliers, such as Asian electronics components or North American raw materials, would rise mechanically alongside the bilateral trade expansion.

Third, the positive spillover may partly reflect the post-2000 proliferation of other preferential agreements involving EU and Mexican partners, which the other-PTA control captures in aggregate but may not fully absorb. The 21.0 per cent estimate should therefore be interpreted as a net effect that pools demand-pull, GVC-complementarity, and residual third-country PTA influences. Distinguishing between these mechanisms empirically is beyond the scope of the present framework, as it would require partner-level disaggregation of the spillover coefficient. This limitation is acknowledged in Section 5.4.

The other-PTA control is 0.078 (approximately 8.1 per cent) and significant at the five per cent level, indicating that other active preferential agreements had a positive average effect on bilateral trade across the sample period.

These findings set the stage for the emissions analysis in Section 4.4, which examines whether the trade expansion identified here translated into proportional changes in embodied CO_2 emissions or whether the composition and technique channels moderated or amplified the environmental impact of the agreement.

As an additional robustness check, the main results reported in Table 2 are evaluated across a series of alternative specifications. Extending the sample period to 1995-2010 yields a larger but qualitatively similar EU-Mexico FTA coefficient. Excluding China from the analytical sample, in order to account for its accession to the WTO in 2001, leaves the EU-Mexico coefficient virtually unchanged at 0.240. Finally, adding a post-treatment interaction for the other-PTA control produces a slightly higher EU-Mexico coefficient of 0.257, while preserving the qualitative pattern of the baseline results. Full results are reported in Appendix A.4.

Table 2: PPML gravity estimates: bilateral trade flows, 1995-2005

Dependent Var.:	model values
EU-MEX FTA (post × EU-MEX)	0.234***
	(0.055)
Spillover: Third → EU or MEX (post × spill)	0.191***
	(0.037)
Other PTAs (active in year t)	0.078*
	(0.039)
Fixed-Effects:	---------
exp_sec_year	Yes
imp_sec_year	Yes
pair_sec	Yes
S.E.: Clustered	by: pair. & year
Squared Cor.	0.99990
Observations	2,045,879
Log-Likelihood	-5,321,349.5
AIC	11,141,003.1
BIC	14,263,211.0
Pseudo R2	0.99851

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

*Note: PPML estimates. Dependent variable is bilateral sectoral export values in current USD. All specifications include exporter×sector×year, importer×sector×year, and exporter-importer×sector fixed effects. Standard errors clustered at the pair×sector and year level are reported in parentheses. Sample covers the analytical period 1995-2005. *** p<0.001, ** p<0.01, * p<0.05, · p<0.1.*

4.4 Gravity results: embodied CO_2 emissions

The trade flow estimations presented in Section 4.3 establish that the EU-Mexico FTA generated substantial trade creation along the bilateral margin and coincided with an expansion of third-country exports toward the EU and Mexico. A central question for the environmental evaluation of the agreement is whether these trade adjustments translated proportionally into changes in embodied CO_2 emissions, or whether the composition of trade and within-sector emission intensities moderated or amplified the carbon consequences of the observed volume effects. This section presents the PPML gravity results with embodied CO_2 emissions as the dependent variable. The emissions specification in equation (10) is estimated under the same fixed-effects structure as the trade flow model.

The comparison between the trade and emissions coefficients is central to the interpretation of this section, as differences in magnitude between the two sets of estimates provide an initial indication of the environmental efficiency of the FTA-induced trade expansion. Results are presented in Table 3.

The coefficient on the direct EU-Mexico effect is 0.164 and statistically significant at the five per cent level, implying that the FTA was associated with an increase in embodied CO_2 emissions of 17.8 per cent relative to the counterfactual of no agreement. Two observations follow directly from a comparison with the corresponding trade coefficient of 0.234. First, the emissions increase is positive and statistically significant, indicating that the agreement had a measurable environmental footprint. Second, the magnitude of the emissions effect is substantially smaller than the trade effect. Bilateral trade increased by approximately 26.4 per cent, creating a gap of roughly 8.6 percentage points. This implies that $\theta_1 < \beta_1$, which according to the framework introduced in Section 3.4.2 is consistent with a cleaner sectoral composition of the additional trade generated by the FTA, a decline in within-sector emission intensities, or both. The FTA therefore appears to have generated trade creation that was relatively less carbon-intensive than the pre-existing trade structure, a finding that motivates the decomposition analysis in Section 4.5.

The spillover coefficient is 0.161 and statistically significant at the 0.1 per cent level, corresponding to an increase of approximately 17.5 per cent in embodied CO_2 emissions associated with third-country exports toward the EU or Mexico in the post-FTA period. Compared with the trade spillover coefficient of 0.191, the emissions and trade effects along the external margin are relatively close, with emissions growing somewhat more slowly than trade volumes (17.5 versus 21.0 per cent). This near-proportionality suggests that third-country exports expanding toward the EU and Mexico carried a broadly similar carbon content per unit of trade relative to the existing structure, although the slightly lower emissions coefficient hints at a marginally cleaner composition of the additional flows. Unlike the direct EU-Mexico margin, where the gap between trade and emissions effects is substantial, the external margin shows a smaller differential.

The other-PTA control is 0.158 (17.1 per cent) and significant at the five per cent level, indicating that other active preferential agreements were associated with a positive average effect on embodied emissions across the sample period.

Overall, the emissions gravity results point to three substantively important conclusions. The EU-Mexico FTA increased embodied CO_2 emissions along the bilateral margin by approximately 17.8 per cent, confirming that the agreement generated a measurable environmental footprint. At the same time, this increase remained substantially smaller than the associated trade expansion of 26.4 per cent, leaving a gap of 8.6 percentage points that suggests the additional trade was meaningfully less carbon-intensive than the pre-existing trade structure. Finally, the external margin exhibits trade and emissions effects that are relatively similar in magnitude (21.0 versus 17.5 per cent), implying that third-country exports expanding into EU and Mexican markets did not systematically differ from the baseline in terms of carbon intensity.

As with the trade specification, the main embodied CO_2 results are robust to the alternative specifications described in Appendix A.4. The EU-Mexico FTA and spillover coefficients retain their sign, significance, and order of magnitude across all robustness checks.

Table 3: PPML gravity estimates: embodied CO_2 in exports, 1995-2005

	model
Dependent Var.:	co2_in_exports
EU-MEX FTA (post × EU-MEX)	0.164*
	(0.070)
Spillover: Third → EU or MEX (post × spill)	0.161***
	(0.038)
Other PTAs (active in year t)	0.158*
	(0.065)
Fixed-Effects:	--------------
exp_sec_year	Yes
imp_sec_year	Yes
pair_sec	Yes
S.E.: Clustered	by: pair. & year
Squared Cor.	0.99997
Observations	1,955,750
Log-Likelihood	-59,925.0
AIC	604,752.0
BIC	3,632,064.2
Pseudo R2	0.95440

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

*Note: PPML estimates. Dependent variable is embodied CO_2 in bilateral sectoral exports, measured in million tonnes of CO_2. All specifications include exporter×sector×year, importer×sector×year, and exporter-importer×sector fixed effects. Standard errors clustered at the pair×sector and year level are reported in parentheses. Sample covers the analytical period 1995-2005. *** p<0.001, ** p<0.01, * p<0.05, · p<0.1.*

4.5 Decomposition results

The decomposition framework is applied to the EU-Mexico bilateral channel, its two directional components (EU-to-Mexico and Mexico-to-EU), and to the two pooled third-country channels (EU-Third and Mexico-Third). The analysis in this section focuses on the bilateral channel and its directional split, which are the primary concern of the research question. Results for the pooled third-country channels are presented in Appendix A.3.

4.5.1 EU-Mexico bilateral channel

The scale-composition-technique decomposition, formalised in equations (11) to (16), is applied to the EU-Mexico bilateral channel in order to identify the mechanisms through which the FTA-attributable trade expansion documented in Section 4.3 translated into changes in embodied CO_2 emissions. The decomposition separates the total FTA-attributable change in emissions into three components: a scale, composition, and technique effect. All components are expressed in model-implied units relative to a common baseline year of 1995, and the decomposition identity holds exactly by construction. The results are presented in Figures 6 to 8 and summarised in Appendix A.2.

Scale effect

The scale component is the dominant and consistently positive driver of FTA-attributable emissions along the EU-Mexico margin. Upon implementation of the agreement in 2000, the scale effect amounts to approximately 1.19 units, representing 34.2 per cent of base-year treated emissions. It grows steadily throughout the post-FTA period, reaching 1.77 by 2005, equivalent to 51.2 per cent of base-year emissions. This monotonic upward trend reflects the progressive expansion of EU-Mexico trade volumes documented in the gravity results, and confirms that the scale channel operates as the primary transmission mechanism from trade liberalisation to emissions.

Composition effect

The composition effect is negative throughout the entire post-FTA period. In 2000, it stands at −0.40 units, equivalent to −11.6 per cent of base-year emissions, and it deepens to a trough of −0.59 in 2003 before partially recovering to −0.47 by 2005. This persistent negative composition effect means that, once weighted by baseline emission intensities, the FTA-attributable reallocation of EU-Mexico trade lowered embodied emissions relative to a proportionally neutral expansion. The effect operates through shifts in the relative sectoral allocation of trade rather than through changes in overall volume, and partially offsets the upward pressure from the scale channel.

The composition effect is computed by subtracting the scale component from the scale-plus-composition counterfactual defined in equation (14). As a complementary descriptive step, Figure 8 provides a sectoral breakdown that identifies which individual sectors moved most strongly behind this aggregate effect. This breakdown is illustrative rather than an alternative computation of the composition effect: it isolates the most active sectors so that the direction of the underlying reallocation becomes visible, while the net composition effect itself is the figure reported in Appendix A.2, Table 5. The largest positive contributions come from basic metals (sector 24) and coke and refined petroleum products (sector 19), followed at distance by chemicals (sector 20) and land transport (sector 49), reflecting gains in trade share in these activities. The largest negative contributions come from water transport (sector 50) and mining and quarrying of energy-producing products (sector 05T06). The figure shows only the sectors reaching the top 15 by absolute contribution in any post-FTA year, and is cumulative over 2000-2005. The displayed bars are therefore best read as a ranking of the most active sectors behind the reallocation, and not as an additive account of the net composition effect. The sector classification itself is provided in Appendix A.1.

It is important to note that a sector's composition contribution depends on how its trade share changes following the FTA, rather than on its absolute level of emissions alone. A highly polluting sector may therefore generate a negative composition contribution if trade in that sector contracts relative to other sectors after the agreement, shifting the overall trade structure away from more emission-intensive activities. Conversely, a sector with moderate absolute emissions may generate a positive contribution if it expanded disproportionately. The composition effect therefore captures changes in the relative sectoral allocation of FTA-attributable trade, weighted by the 1995 baseline emission intensities.

Technique effect

The technique effect is negative throughout the post-FTA period, indicating a decline in within-sector emission intensities relative to the 1995 baseline. In 2000, the technique effect stands at −0.26 units, or −7.4 per cent of base-year emissions. It remains broadly stable through 2003 at approximately −0.23 to −0.31, before deepening markedly to −0.51 in 2004 and −0.65 in 2005. This acceleration in the later years of the sample suggests that the technique channel becomes increasingly important over time, consistent with the literature on learning-by-doing and technology diffusion through trade integration, whereby firms exposed to international competition gradually adopt cleaner production technologies (Copeland, Shapiro, & Taylor, 2021).

As defined in equation (16), the technique effect is computed as a residual and therefore captures all changes in within-sector emission intensities not explained by scale or composition adjustments. It should be interpreted accordingly, as it may also absorb measurement error and model misspecification rather than reflecting genuine technological improvement exclusively.

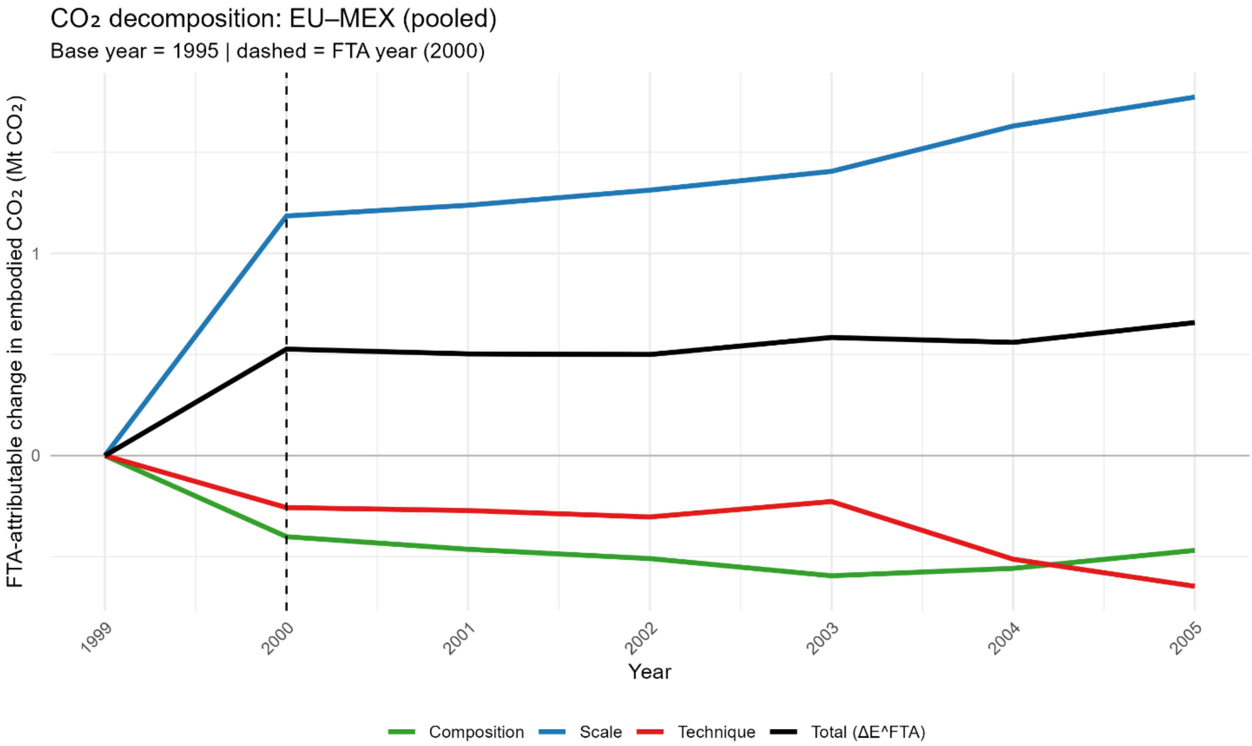
Net effect and the scale-composition-technique balance

The total FTA-attributable change in embodied CO_2 emissions along the EU-Mexico margin is positive throughout the post-FTA period, ranging from 0.53 in 2000 to 0.66 in 2005. Expressed relative to base-year treated emissions, the total effect lies between 14.5 and 19.0 per cent across post-FTA years. This range overlaps closely with the gravity-based emission coefficient of 17.8 per cent, supporting the internal coherence of the integrated approach. The two measures are not directly comparable in interpretation since the gravity coefficient captures the average proportional shift in the conditional mean while the decomposition total reflects the absolute FTA-attributable change relative to 1995 baseline levels, but their convergence in magnitude is reassuring.

The decomposition reveals a structural imbalance between the three channels. The scale effect consistently exceeds the total emissions change by a factor of approximately two to three, meaning that the gross emissions pressure from trade expansion is substantially larger than the net observed effect. The negative composition and technique effects together offset between 55 and 66 per cent of the scale component in most years, preventing a proportional translation of trade growth into emissions growth. This finding is directly consistent with the gap between the trade and emissions gravity coefficients identified in Section 4.4, and provides a mechanistic explanation for that gap. The FTA generates trade creation that is compositionally skewed toward cleaner sectors and accompanied by declining within-sector emission intensities.

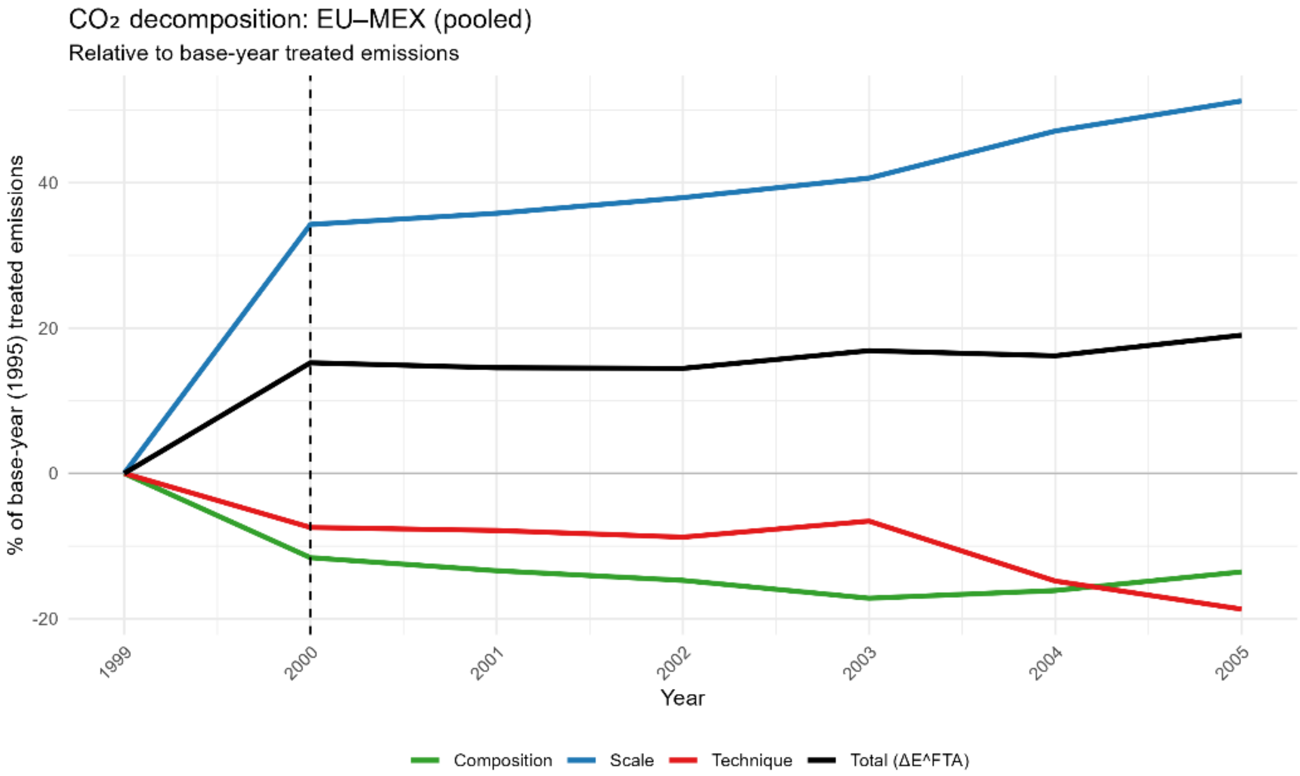
Figure 6 illustrates the divergence between these components graphically. The scale effect grows continuously and without interruption throughout the sample period, reflecting the sustained expansion of FTA-attributable trade volumes. The total emissions change, by contrast, remains comparatively flat and is held in check by the offsetting contributions of composition and technique. Figure 7 presents the same decomposition expressed as a percentage of base-year treated emissions, confirming that the structural pattern is robust to the choice of scale.

Figure 6: CO_2 decomposition EU-Mexico (pooled), absolute FTA-attributable changes, 2000-2005



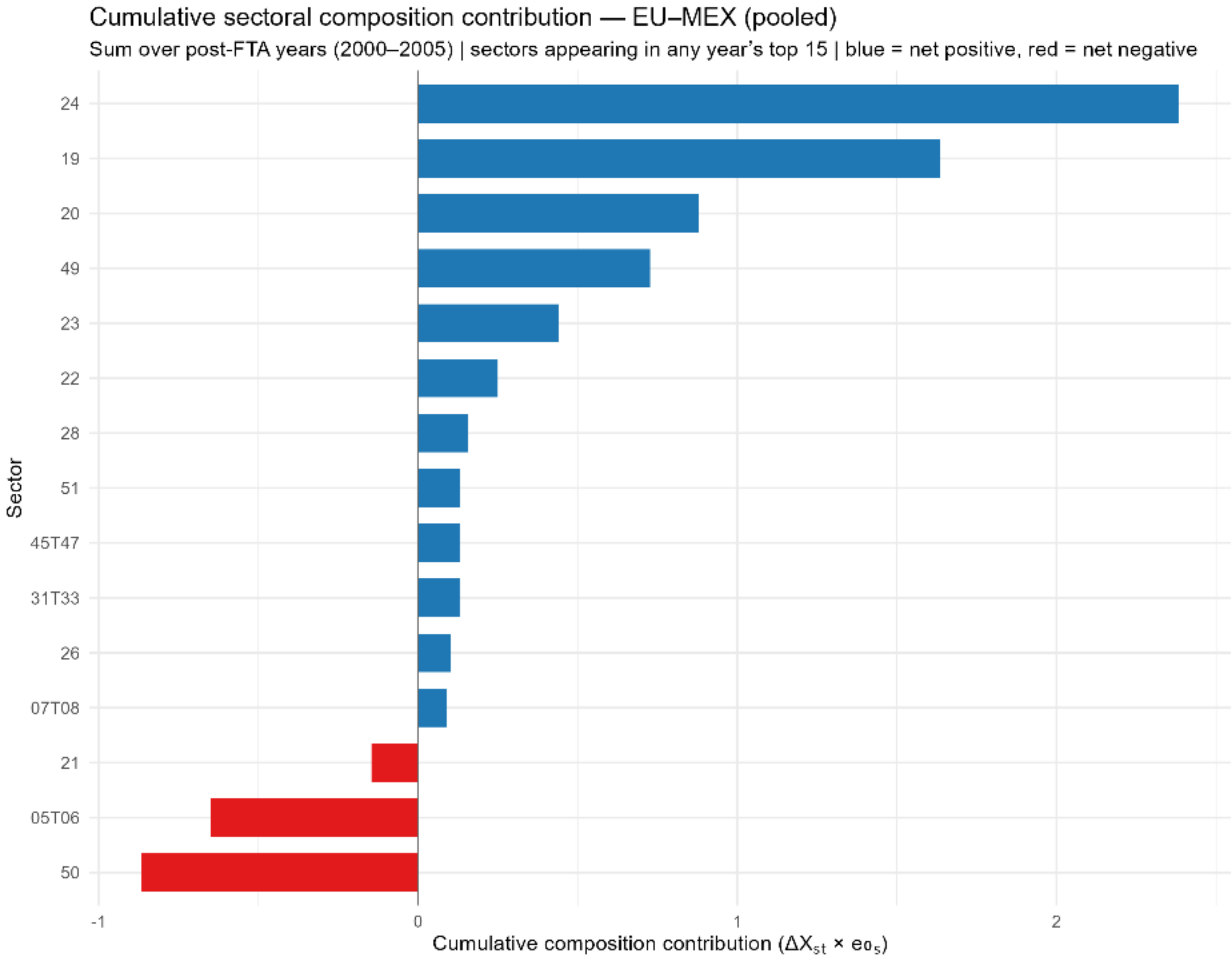
Note: Scale-composition-technique decomposition of FTA-attributable changes in embodied CO_2 along the pooled EU-Mexico bilateral margin, expressed in million tonnes of CO_2 relative to the 1995 baseline. The scale component reflects the emissions change attributable to the FTA-induced increase in aggregate trade volumes, weighted by the 1995 baseline emission intensity. The composition component captures the reallocation of trade across sectors with different baseline carbon intensities. The technique component is recovered as the residual between total FTA-attributable emissions and the scale-plus-composition component. The dashed vertical line indicates the year the EU-Mexico FTA entered into force (2000).

Figure 7: CO_2 decomposition EU-Mexico (pooled), relative to base-year treated emissions, 2000-2005



Note: Same decomposition as Figure 6, expressed as a percentage of base-year (1995) treated emissions along the EU-Mexico bilateral margin. This scaling allows the magnitude of each component to be interpreted relative to the pre-FTA emissions level on the treated trade route.

Figure 8: Cumulative sectoral composition contribution EU-Mexico (pooled), 2000-2005



Note: Cumulative composition contribution by sector, summed over the post-FTA period 2000-2005. Each bar shows the sector's total contribution to the composition effect, computed as the FTA-attributable trade delta multiplied by the sector's 1995 baseline emission intensity ($\Delta X_{st} \times e_{sb}$), summed across all post-FTA years. Blue bars indicate a net positive contribution to embodied CO_2 (carbon-intensive sectors gaining trade share); red bars indicate a net negative contribution. Only sectors appearing in any year's top 15 by absolute contribution are shown. Sector codes follow the OECD ICIO industry classification. Because only top-15 sectors are shown and contributions are cumulated over 2000-2005, the displayed bars do not sum to the net composition effect reported in the corresponding decomposition table. Full sector descriptions are provided in Appendix A.1.

4.5.2 Directional decomposition: EU to Mexico and Mexico to EU

The pooled bilateral decomposition presented in Section 4.5.1 aggregates over both directions of EU-Mexico trade. Disaggregating by direction reveals important asymmetries in the scale, composition, and technique channels that the pooled results necessarily obscure. This subsection examines the EU to Mexico and Mexico to EU channels separately, with results presented in Tables 6 and 7 (see Appendix A.2) and illustrated in Figures 9 through 12.

EU to Mexico channel

The EU to Mexico channel is the larger of the two directional flows in terms of FTA-attributable scale pressure. The scale effect rises from 0.72 in 2000 to 1.10 by 2005, equivalent to 46.4 and 70.4 per cent of base-year treated emissions respectively. This sustained and accelerating scale expansion reflects the preferential market access gained by European exporters following the agreement and is the dominant source of upward emissions pressure along this margin.

The composition effect is negative throughout the sample period, declining from −0.19 in 2000 to a trough of −0.32 in 2003 before partially recovering to −0.12 by 2005. This negative composition effect indicates that EU exports to Mexico following the FTA were disproportionately concentrated in sectors with below-average emission intensities at baseline. The smaller absolute effect observed in 2005 suggests a partial convergence toward a more proportionally neutral sectoral distribution of EU exports as the agreement matures. The sectoral decomposition in Figure 11 identifies which sectors move most along this margin. Basic metals (sector 24) and coke and refined petroleum products (sector 19) generate the largest positive contributions, gaining trade share, while water transport (sector 50) is the largest negative contributor, followed by mining of energy-producing products (sector 05T06). As in the pooled channel, the figure displays only the sectors reaching the top 15 in any post-FTA year and is cumulative over 2000-2005, so the displayed bars rank the most active sectors rather than providing an additive account of the net composition effect, which is reported in Appendix A.2, Table 6.

The technique effect is small and negative in the early post-FTA years, standing at −0.13 in 2000 and remaining modest through 2003, before deepening markedly to −0.38 in 2004 and −0.58 in 2005. This sharp acceleration in the technique channel during the final years of the sample may reflect a gradual decline in the emission intensity of European export sectors, driven by stricter EU environmental regulation and supply-side technological progress. Alternatively, it may reflect a compositional reallocation in which cleaner production stages were increasingly retained within the EU, while more emission-intensive activities were shifted abroad. The timing of the decline also suggests that part of the effect may be related to broader structural changes associated with the 2004 EU enlargement, which incorporated new member states into the treated sample and may have altered the composition of EU-Mexico trade relationships.

The total FTA-attributable change in embodied emissions along the EU-to-Mexico margin is positive and remains remarkably stable over the post-FTA period, ranging between 0.38 and 0.42. Expressed relative to base-year emissions, this corresponds to an increase of approximately 24 to 27 per cent, which is notably higher than the pooled bilateral estimate of 14 to 19 per cent. This implies that European exports to Mexico generate a proportionally larger emissions footprint than the bilateral average, and that the stabilising influence of composition and technique offsets is less complete along this directional margin than in the pooled channel.

Mexico to EU channel

The Mexico to EU channel presents a structurally distinct decomposition pattern that contrasts sharply with the EU to Mexico results on two dimensions: the absolute magnitude of effects and the relative importance of the composition channel.

The scale effect in this channel is substantially smaller in absolute terms, rising from 0.34 in 2000 to 0.49 in 2005. This is expected given the inherent asymmetry in economic size between the two partners. Relative to base-year treated emissions, this represents 17.8 to 25.7 per cent, comparable in proportional terms to the EU to Mexico channel, confirming that both directions experienced similar proportional trade expansion following the agreement.

The composition effect is, however, markedly more negative in this channel, declining from −0.20 in 2000 to −0.31 in 2005 and deepening persistently throughout the sample period without the partial recovery observed in the EU to Mexico channel. Expressed relative to base-year emissions, the composition effect reaches −16.4 per cent by 2005, more than double the corresponding figure for the EU to Mexico direction. This large and deepening negative composition effect indicates that Mexican exports toward the EU were strongly concentrated in cleaner sectors relative to the 1995 baseline structure, and that this concentration intensified over time. The sectoral decomposition in Figure 12 shows that chemicals (sector 20) is the largest positive contributor by a wide margin, reflecting a strong gain in trade share, while mining of energy-producing products (sector 05T06) is the largest single negative contributor, followed at distance by pharmaceuticals (sector 21). As with the other channels, the figure displays only the top-15 sectors in any post-FTA year, summed over 2000-2005, and does not sum to the net composition effect in Appendix A.2, Table 7.

This asymmetry between the two directional channels admits several interpretations. One possibility is that Mexican exports to the EU expanded disproportionately in sectors with relatively lower baseline emission intensities, reflecting changes in Mexico's export structure following the agreement. Another potential explanation for this asymmetry lies in the structure of preferential tariff reductions embedded in the EU-Mexico FTA. Shapiro (2021) documents a systematic environmental bias in trade policy, whereby tariff schedules tend to impose lower barriers on relatively clean sectors than on emission-intensive ones. If preferential tariff reductions under the EU-Mexico agreement were more pronounced in relatively cleaner sectors than in more emission-intensive industries, the agreement would induce a compositional shift in Mexican exports toward the EU in favour of lower-emission activities. This shift would occur independently of Mexico's underlying comparative advantage in emission-intensive production. Under this interpretation, the negative composition effect along the Mexico to EU margin would reflect the tariff architecture of the agreement rather than a genuine structural reorientation of Mexican production toward cleaner activities.

The technique effect in the Mexico to EU channel is small and oscillates around zero throughout the post-FTA period, ranging from approximately −0.02 to +0.07. This near-zero technique effect stands in stark contrast to the strongly negative and accelerating technique component observed in the EU to Mexico channel, and suggests that within-sector emission intensities in Mexican export sectors toward the EU changed little over the sample period relative to baseline.

This near-zero technique effect is somewhat counterintuitive, as standard trade-environment theory would predict that integration with a high-income trading partner such as the EU should facilitate technology diffusion and reduce within-sector emission intensities in Mexican export sectors over time (Antweiler, Copeland, & Taylor, 2001). Several explanations may account for this finding. First, the near-zero technique effect may simply reflect the short time horizon of the analytical sample: technology diffusion through trade integration typically materialises over longer periods than the six post-FTA years covered here. Second, the strongly negative technique component observed in the EU to Mexico channel should not necessarily be interpreted as evidence of technological improvement on the Mexican side.

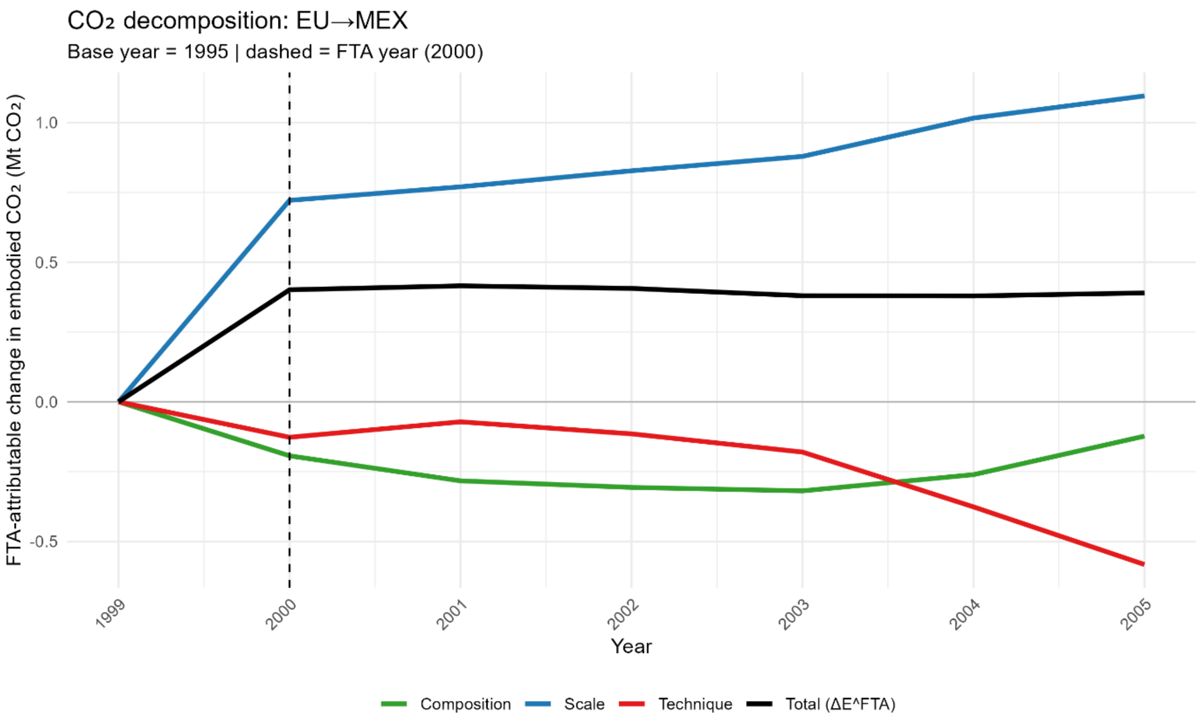
If European firms offshored emission-intensive production stages to Mexico while greening their domestic operations, the emission intensity of EU exports to Mexico would decline mechanically. This would not necessarily indicate cleaner production in Mexico, but rather that the EU retained a larger share of the cleaner stages of production. Under this interpretation, the near-zero technique component in the Mexico to EU channel is the more informative result: it indicates that the carbon intensity of Mexican exports toward the EU remained broadly stable, suggesting that any technology diffusion through the FTA had not yet translated into measurable within-sector improvements over this period. Third, as noted in Section 3.5.5, the technique effect is computed as a residual and is mechanically constrained when the composition channel dominates, as is the case here.

The total FTA-attributable emissions change along the Mexico to EU margin is positive but small, rising from 0.15 in 2000 to 0.25 in 2005, substantially below the EU to Mexico total despite comparable proportional scale effects. Expressed relative to base-year emissions, the total effect reaches 13.2 per cent by 2005. The lower net emissions impact relative to the EU to Mexico direction reflects the dominant role of the composition channel: the strong negative composition effect absorbs a large fraction of the positive scale effect, constraining the net emissions outcome to a level well below what the aggregate trade expansion alone would imply.

Taken together, the directional decomposition reveals a systematic asymmetry in the environmental transmission of the EU-Mexico FTA. Along the EU to Mexico margin, scale effects are large and growing, while composition effects are negative but relatively modest, and the technique channel provides an accelerating offsetting contribution primarily in the later years of the sample. Along the Mexico to EU margin, scale effects are smaller in absolute terms, but the composition channel is substantially more negative and more persistent, generating a structurally more favourable emissions outcome per unit of FTA-attributable trade.

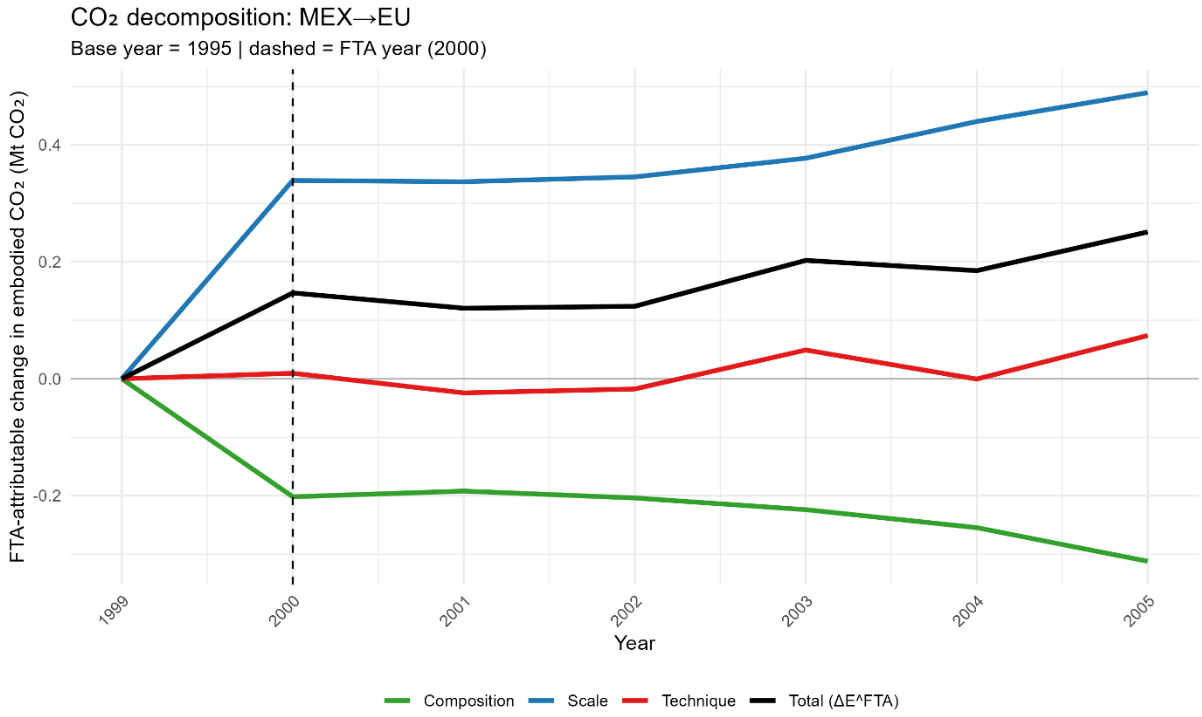
This asymmetry has a direct implication for the environmental evaluation of the agreement. The emissions increase associated with the FTA is not uniformly distributed across the bilateral relationship. In absolute terms, European exports to Mexico generate a larger FTA-attributable emissions footprint, though this partly reflects the structural size difference between the EU and Mexico as trading partners rather than an inherently more carbon-intensive export composition. Along the Mexico to EU margin, the strong negative composition effect partially decouples trade expansion from emissions growth, resulting in a substantially lower net emissions outcome per unit of FTA-attributable trade. The net bilateral emissions effect documented in the pooled results of Section 4.5.1 therefore conceals an important directional heterogeneity that is relevant both for interpreting the environmental consequences of the agreement and for informing the design of future trade and climate policy instruments.

Figure 9: CO_2 decomposition EU→Mexico, absolute FTA-attributable changes, 2000-2005



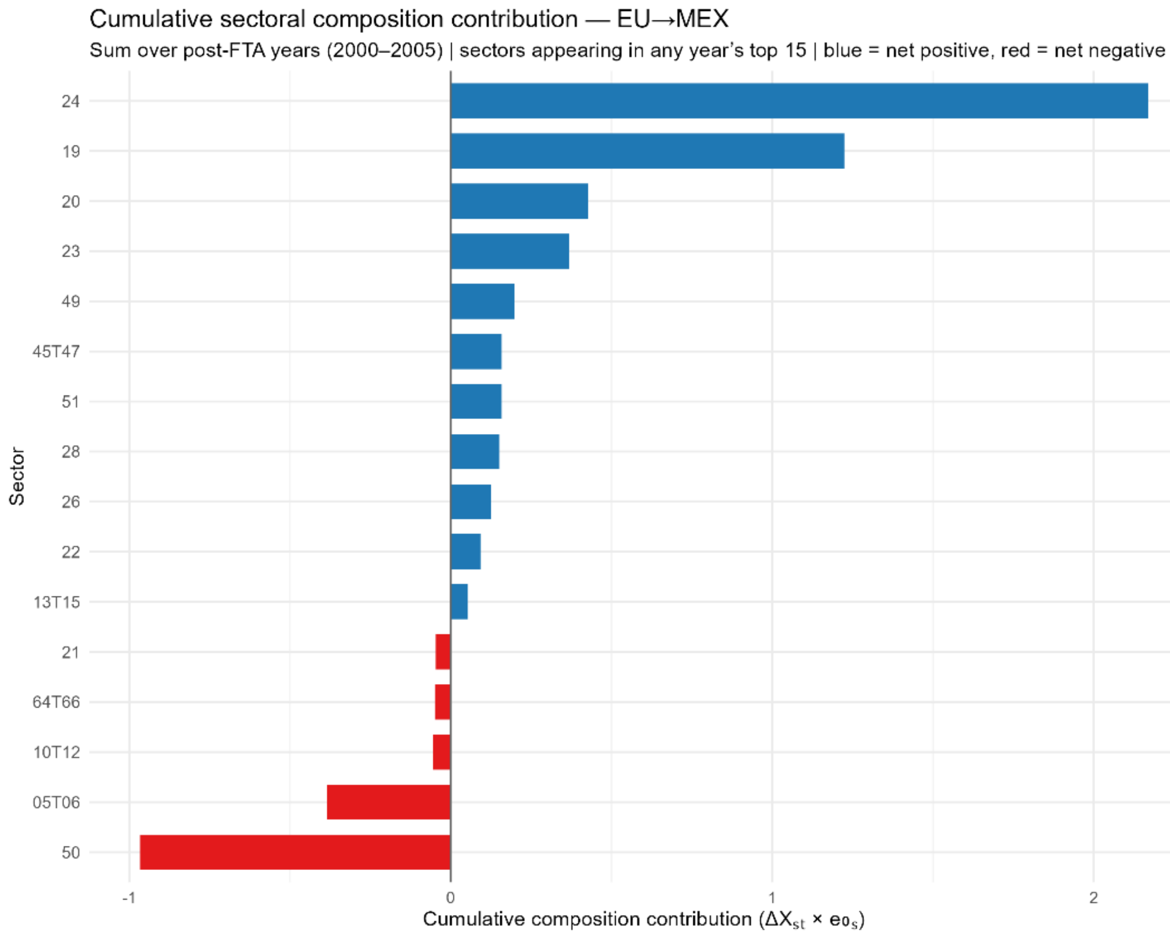
Note: Scale-composition-technique decomposition of FTA-attributable changes in embodied CO_2 along the EU to Mexico directional margin, expressed in million tonnes of CO_2 relative to the 1995 baseline. The scale component reflects the emissions change attributable to the FTA-induced increase in aggregate trade volumes, weighted by the 1995 baseline emission intensity. The composition component captures the reallocation of trade across sectors with different baseline carbon intensities. The technique component is recovered as the residual between total FTA-attributable emissions and the scale-plus-composition component. The dashed vertical line indicates the year the EU-Mexico FTA entered into force (2000).

Figure 10: CO_2 decomposition Mexico→EU, absolute FTA-attributable changes, 2000-2005



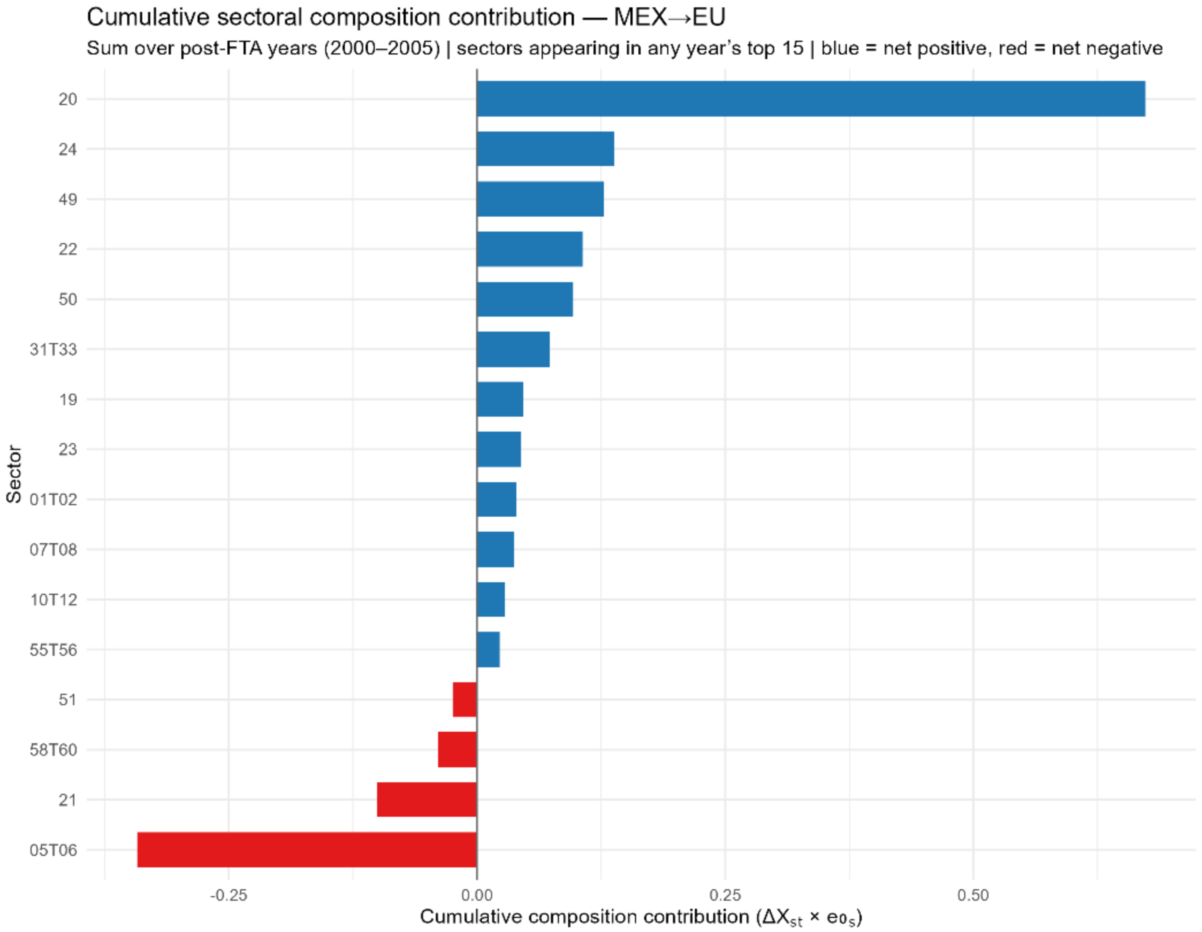
Note: Same decomposition as Figure 9, applied to the Mexico to EU directional margin, expressed in million tonnes of CO_2 relative to the 1995 baseline. All components are defined identically; differences in magnitude and sign reflect the asymmetric trade and emissions response along this direction of the bilateral relationship.

Figure 11: Cumulative sectoral composition contribution EU→Mexico, 2000-2005



Note: Cumulative composition contribution by sector along the EU to Mexico directional margin, summed over the post-FTA period 2000-2005. Each bar shows the sector's total contribution to the composition effect, computed as the FTA-attributable trade delta multiplied by the sector's 1995 baseline emission intensity ($\Delta Xst \times esb$), summed across all post-FTA years. Blue bars indicate a net positive contribution to embodied CO_2; red bars indicate a net negative contribution. Only sectors appearing in any year's top 15 by absolute contribution are shown. Sector codes follow the OECD ICIO industry classification. Because only top-15 sectors are shown and contributions are cumulated over 2000-2005, the displayed bars do not sum to the net composition effect reported in the corresponding decomposition table. Full sector descriptions are provided in Appendix A.1.

Figure 12: Cumulative sectoral composition contribution Mexico→EU, 2000-2005



Same as Figure 11, applied to the Mexico to EU directional margin. Differences in sectoral ranking and sign pattern relative to Figure 11 reflect the distinct composition of trade flows along this direction of the bilateral relationship. Because only top-15 sectors are shown and contributions are cumulated over 2000-2005, the displayed bars do not sum to the net composition effect reported in the corresponding decomposition table. Full sector descriptions are provided in Appendix A.1.

4.6 Discussion and contextual assessment

4.6.1 Trade creation in comparative perspective

The gravity results indicate bilateral trade creation of 26.4 per cent. Before turning to the environmental implications, it is worth situating this magnitude relative to the broader literature on trade agreement effects. Larch and Yotov (2024), reviewing sixty years of gravity-based RTA estimates, find that the most methodologically rigorous specifications converge toward a positive average RTA effect of around 22 per cent on bilateral trade flows. Magee (2008) similarly finds that gravity estimates of RTA trade effects shrink substantially once dyad, exporter-year, and importer-year fixed effects are introduced. His most demanding specification yields a cumulative RTA effect of 21.7 per cent that is not statistically distinguishable from zero.

The EU-Mexico estimate sits above this benchmark, suggesting the agreement generated trade creation that exceeds the typical RTA effect, despite being a first-generation agreement focused primarily on tariff elimination rather than the deeper regulatory integration of more recent EU trade deals (Ecorys, 2017). This is notable because the European Commission's Impact Assessment (2015) explicitly argued that the original agreement had become insufficiently ambitious relative to newer-generation FTAs, implying expectations of relatively modest trade effects. The gravity result challenges that reading, at least in terms of the trade volume response.

Ecorys (2017), using a cross-sectional gravity model based on 2011 trade and policy data, concluded that the existing agreement generated no measurable additional trade beyond what tariff elimination alone would predict, with exceptions confined to aerospace and petrochemicals. The divergence with the present estimate is largely methodological: a single cross-section cannot identify the pre-post treatment shift that a panel DiD strategy isolates. The Ecorys (2017) analysis asked whether trade exceeded gravity model predictions at a given point in time. This thesis asks how trade changed between the pre-FTA and post-FTA periods relative to untreated country pairs. These are different questions, and the two results are not mutually contradictory.

Bui (2023), applying an analogous gravity specification to the EU-Korea FTA, finds an asymmetric trade response in which the EU-to-Korea direction dominates. While direct comparison of coefficient magnitudes across the two studies is complicated by differences in data vintage, country scope, and sample period, the EU-Mexico bilateral trade effect of 26.4 per cent is broadly in the same order of magnitude as the EU-Korea results, suggesting that both agreements generated substantive but not exceptional trade creation when placed against the full distribution of RTA estimates documented by Larch and Yotov (2024).

4.6.2 The trade-emissions gap and its implications

The central finding from the emissions gravity model is a 17.8 per cent increase in embodied CO_2 along the bilateral margin, against a trade increase of 26.4 per cent. The resulting gap of approximately 8.6 percentage points indicates that the additional trade induced by the FTA was meaningfully less carbon-intensive than the pre-existing trade structure. This gap is substantial in absolute terms and is consistent in direction with what the SCT decomposition confirms mechanistically: composition and technique channels both offset a portion of the gross scale pressure.

To judge whether 8.6 percentage points constitutes a large or small environmental adjustment, it helps to frame it against other evidence. Ecorys (2017) reports that the CGE-based analysis finds a net global CO_2 increase of approximately 600,000 tonnes attributable to the existing agreement, corresponding to roughly 0.015 per cent of the EU's annual emissions. That figure is expressed in absolute, economy-wide terms and is therefore not directly comparable to the gravity estimate, which is a percentage effect on the bilateral embodied-emissions channel only.

The bilateral channel nevertheless represents only a small share of the overall emissions profile of either partner, so the corresponding absolute FTA-attributable increase in embodied CO_2 reaches only 658,000 tonnes by 2005 (Appendix A.2, Table 5). The two findings are therefore broadly consistent: the agreement generated a meaningful proportional environmental effect along the bilateral trade margin, while the corresponding absolute increase in emissions remained limited.

The Commission's Impact Assessment (2015) projects similarly modest environmental effects under prospective modernisation scenarios, estimating changes on the order of fractions of a per cent of total national emissions, even under ambitious liberalisation. The convergence across three distinct methodological approaches (structural gravity, CGE simulation, and ex ante impact assessment) in identifying small absolute environmental effects is reassuring. Where this thesis adds to that picture is in the direction and mechanism. Rather than simply reporting a small net effect, the decomposition shows why it is small. The scale channel generates persistent upward pressure, while the composition and technique channels together offset between 55 and 66 per cent of that pressure in the post-FTA years. The environmental modesty of the agreement is not coincidental but reflects active structural adjustment in the composition of trade.

The EU-Korea comparison sharpens this interpretation. Bui (2023) finds an average increase of 29.6 per cent in CO_2 embodied in EU-to-Korea trade, driven almost entirely by the scale channel with composition effects playing a secondary role. This is structurally different from the EU-Mexico result, where composition and technique jointly contain the scale pressure. Part of this contrast likely reflects the different sectoral composition of the two bilateral relationships. EU-Korea trade is heavily concentrated in manufacturing sectors with strong comparative advantage in pollution-intensive activities such as coke and petroleum products, while EU-Mexico trade, though also manufacturing-intensive, includes a broader mix of assembled goods and intermediates with more heterogeneous emission intensities. Bui also finds no significant emissions effect along the Korea-to-EU direction, an asymmetry that is more pronounced than what the present thesis finds for the Mexico-to-EU channel, where a positive but substantially offset total effect is documented.

4.6.3 The spillover margin and the absence of diversion

The spillover coefficient is positive and significant both for trade (approximately 21 per cent) and for emissions (17.5 per cent). The near-proportionality of these two effects implies that third-country exports expanding into EU and Mexican markets carried broadly unchanged carbon content per unit of trade, with only a marginal emissions-side adjustment relative to trade volumes. This contrasts with the direct bilateral channel, where the trade-emissions gap of 8.6 percentage points signals genuine compositional improvement.

The qualitative finding, that the FTA was associated with third-country trade expansion rather than diversion, is broadly aligned with the EU-Korea evidence in Bui (2023), where third-country flows are absorbed through a general RTA control rather than separately identified, but show no indication of being displaced by the agreement. Together this suggests a common pattern across recent EU agreements.

Ecorys (2017) does not report a separately identified spillover coefficient in its gravity analysis, so direct numerical comparison is not possible. The CGE results, however, do show third-country effects at the aggregate level, finding small CO_2 increases in Canada and the EU partly offset by reductions in Mexico and the United States. These aggregate flows are consistent with an interpretation in which the agreement stimulated broader trade rather than substituting selectively for third-country supply.

As discussed in Section 4.3, the spillover coefficient may reflect demand-pull effects, global value chain complementarity, or residual third-country PTA influences. These mechanisms are not mutually exclusive and the present empirical design cannot disentangle their respective contributions to the spillover coefficient. This conclusion is robust to that ambiguity, but the precise channel through which it operates remains an open question. Section 5.4 returns to this point as a direction for future research.

4.6.4 The directional asymmetry in environmental terms

The decomposition results reveal a structural asymmetry that the gravity-level comparison does not fully capture. Along the EU-to-Mexico margin, scale effects are large and growing, reaching over 70 per cent of base-year treated emissions by 2005, while composition and technique provide meaningful but incomplete offsets. The net emissions effect along this channel, approximately 24 to 27 per cent relative to base-year emissions, is proportionally higher than the pooled bilateral estimate and substantially higher than the Mexico-to-EU total of around 13 per cent by 2005.

The Mexico-to-EU channel is distinguished by a composition effect that is both more negative and more persistent than its EU-to-Mexico counterpart, reaching −16.4 per cent of base-year emissions by 2005. This strong compositional adjustment, partly attributable to the tariff architecture argument of Shapiro (2021) and partly to Mexico's integration into assembled manufacturing supply chains, produces a substantially lower net emissions outcome per unit of FTA-attributable trade. The near-zero technique effect along this direction, discussed at length in Section 4.5.2, indicates that within-sector emission intensities in Mexican export sectors toward the EU remained broadly stable, so the relatively favourable environmental outcome is driven by composition rather than technological change.

This directional asymmetry has a parallel in the EU-Korea literature. Bui (2023) finds that the emissions effect of the EU-Korea FTA is concentrated in the EU-to-Korea direction, with the scale channel dominant and the composition channel playing only a secondary role. The absence of a significant Korea-to-EU emissions effect corresponds to the near-zero net effect found along the Mexico-to-EU margin in this thesis, though the mechanism differs. In the Korea case the scale effect itself appears limited in the reverse direction, while in the Mexico case the scale effect is present but substantially absorbed by composition. Both cases point toward the same underlying conclusion: that the environmental character of trade liberalisation is asymmetric across the two directions of a bilateral FTA, and that this asymmetry is largely determined by the sectoral structure of comparative advantage rather than by the agreement's environmental provisions, which in the EU-Mexico case are negligible. These findings, taken together with the gravity and decomposition results presented earlier in this chapter, provide the empirical basis for the conclusions and policy implications developed in Chapter 5.

5. Conclusion

5.1 Summary of the research objective and empirical findings

This thesis set out to answer a question that sits at the intersection of trade policy and environmental economics: to what extent has the EU-Mexico Free Trade Agreement, which entered into force in 2000, influenced trade flows and the distribution of embodied CO_2 emissions between the European Union, Mexico, and third-country partners?

The motivation for this question is both empirical and methodological. From an empirical perspective, the EU-Mexico agreement is one of the longest-standing comprehensive trade agreements in EU history. Yet its realised environmental consequences have not previously been assessed through an ex post econometric framework that directly links observed trade adjustments to changes in embodied emissions. Existing evaluations, including the Ecorys (2017) ex post report and the European Commission's impact assessment (2015) for modernisation, relied on CGE-based simulation to quantify environmental effects. These approaches derive outcomes from calibrated model structures rather than from observed post-agreement trade reallocation, and they systematically omit the technique channel. The conclusion that environmental effects are small therefore reflects the architecture of the models as much as the underlying reality.

On the methodological side, this thesis develops and applies a unified empirical strategy that connects structural gravity modelling with input-output-based environmental accounting and a scale-composition-technique decomposition. Rather than asking what an agreement is expected to do, it asks what the agreement demonstrably did, using variation in bilateral trade flows across treated and untreated country pairs before and after 2000 to identify causal effects. By estimating parallel gravity models for trade flows and embodied CO_2 emissions, and by decomposing the resulting emissions changes into scale, composition, and technique components, the analysis provides a mechanistic account of how the agreement's economic effects translated into environmental outcomes. This integrated approach, replicable across other agreements and data vintages, represents the core methodological contribution of the thesis alongside its substantive findings on the EU-Mexico case.

The empirical analysis provides a direct and differentiated answer to the research question. The EU-Mexico FTA generated bilateral trade creation of 26.4 per cent and a positive spillover toward third countries, with no evidence of classical trade diversion. Embodied CO_2 emissions along the bilateral trade margin increased by 17.8 per cent, less than proportionally to the associated expansion in trade flows.

The resulting 8.6 percentage-point gap reflects a structural characteristic of the agreement rather than a measurement artefact: the additional bilateral trade was disproportionately concentrated in sectors with below-average baseline emission intensities, while within-sector emission intensities declined over the post-FTA period. The scale-composition-technique decomposition confirms this mechanism, showing that the composition and technique channels jointly offset between 55 and 66 per cent of the gross scale-driven increase in emissions during most post-FTA years.

The environmental effects of the agreement are also unevenly distributed across the two directions of bilateral trade. EU exports to Mexico exhibit a proportionally larger FTA-attributable carbon footprint, reaching approximately 24 to 27 per cent of base-year emissions by 2005. By contrast, Mexican exports to the EU undergo a substantially cleaner compositional adjustment toward lower-emission manufacturing activities, limiting the net emissions increase to roughly 13 per cent over the same period. The environmental transmission of the agreement is therefore both limited in aggregate magnitude and structurally asymmetric across the two bilateral directions, a pattern that simulation-based evaluations are generally unable to identify but that emerges clearly from the observed-data empirical framework employed in this thesis.

5.2 Contribution to the literature

This thesis makes three distinct contributions that together advance the empirical literature on trade agreements and the environment.

The first and most direct contribution is an ex post econometric assessment of the environmental consequences of the EU-Mexico Free Trade Agreement based on realised trade and emissions data. To this day, no prior study has assessed the environmental consequences of the agreement by directly linking observed post-FTA trade reallocation to changes in embodied emissions through an econometric framework. The European Commission's Impact Assessment (2015) is explicitly ex ante in nature, relying on simulated projections rather than realised outcomes. Although the Ecorys (2017) ex post evaluation incorporates observed trade and economic data, its environmental conclusions are still derived from a CGE-based modelling extension rather than from directly observed adjustments in embodied CO_2 emissions.

This thesis fills that gap by identifying FTA-attributable changes in embodied CO_2 emissions directly from panel data, using the same DiD logic embedded in a structural gravity framework that has become standard for evaluating the economic effects of trade agreements. These findings constitute a substantive contribution that simulation-based approaches are not able to identify. They also qualify the conclusion, common to both the Ecorys report (2017) and the Commission's impact assessment (2015), that the environmental effects of the agreement are simply small. While the effects are small in absolute terms, they remain structurally meaningful in terms of the channels through which trade expansion translates into emissions.

The second contribution is methodological and concerns the integration of gravity-based trade estimation with input-output-based environmental accounting within a single unified framework. The thesis estimates parallel PPML gravity models for bilateral trade flows and embodied CO_2 emissions under identical specifications and fixed-effects structures, and uses the resulting coefficients jointly to implement a scale-composition-technique decomposition. This design ensures that differences between trade and emissions coefficients are interpretable as genuine environmental signals rather than artefacts of specification differences. The decomposition components, formally defined in equations (11) to (16), are internally consistent with the underlying gravity estimates from equations (9) and (10).

The broad consistency in order of magnitude between the gravity-based emissions coefficient and the decomposition total supports the internal coherence of the integrated approach, though the two measures are not directly comparable in scale. The framework is replicable across other agreements, data vintages, and partner combinations, and offers a practical template for environmental evaluation that does not rely on the structural assumptions of CGE models.

The third contribution concerns the directional and channel-level granularity of the environmental analysis. Existing studies of trade agreements and embodied emissions, including the closest methodological precedent in Bui (2023) on the EU-Korea FTA, tend to report aggregate or single-direction results. This thesis demonstrates that aggregation conceals important heterogeneity. The EU-to-Mexico and Mexico-to-EU channels differ substantially in the relative weight of scale, composition, and technique effects, and pooling them produces a bilateral average that accurately describes neither direction individually.

The finding that the Mexico-to-EU composition effect is more than twice as large as its EU-to-Mexico counterpart, and that this asymmetry is consistent with both the tariff architecture argument of Shapiro (2021) and Mexico's integration into assembled manufacturing supply chains, illustrates that directional decomposition is not merely a refinement but a substantively informative analytical step. This granularity is relevant for any environmental evaluation that aims to identify which partner bears the carbon cost of trade liberalisation and through which mechanism.

5.3 Policy implications

The empirical findings of this thesis carry several implications for the design and evaluation of trade policy in an era where climate objectives are increasingly central to the EU's external agenda.

The most immediate implication concerns the environmental assessment methodology used by the European Commission (2015). The finding that the EU-Mexico FTA generated a measurable and structurally differentiated environmental footprint, one that existing CGE-based evaluations were unable to identify with precision, points toward a methodological gap in current practice. Sustainability Impact Assessments and ex post evaluations continue to rely on simulation frameworks that hold emission intensities fixed, omit the technique channel, and cannot capture the causal trade reallocation dynamics that drive embodied emissions outcomes. The integrated gravity-decomposition approach developed in this thesis provides a tractable alternative that could be integrated into standard FTA evaluation frameworks.

This has become increasingly feasible with the availability of the OECD ICIO-TiVA database, which offers consistent input-output and emissions data across countries and trade agreements. As the EU continues to negotiate and modernise trade agreements with partners at different levels of environmental regulation, the ability to identify realised environmental effects from observed data rather than simulated scenarios becomes increasingly policy-relevant.

The second implication concerns the modernisation of the EU-Mexico agreement itself. The finding that bilateral trade creation exceeded the typical RTA benchmark, and that the associated emissions increase was moderated by compositional and technical adjustment rather than by any explicit environmental provision in the agreement, raises a question about the role of environmental architecture in trade deals. The original EU-Mexico agreement contains no meaningful environmental clauses, yet the composition of the additional trade it generated was systematically skewed toward cleaner sectors. This outcome appears to reflect the structure of comparative advantage and the tariff architecture of the agreement rather than deliberate environmental design.

The modernised agreement, concluded in 2018 and incorporating a dedicated trade and sustainable development chapter, offers an opportunity to move from incidental environmental outcomes to intentional ones. The evidence in this thesis suggests that the channel through which that intention should operate is primarily compositional. Instruments that shape the sectoral structure of preferential liberalisation, such as differential tariff schedules that avoid extending the largest preferences to emission-intensive sectors, are more likely to generate environmental gains than generic sustainability language.

Third, the directional asymmetry documented in the decomposition has implications for how the environmental costs and benefits of trade liberalisation are distributed across partners. The finding that EU exports to Mexico carry a proportionally larger FTA-attributable emissions footprint than Mexican exports to the EU, and that the Mexico-to-EU channel is subject to a stronger compositional adjustment, implies that the environmental burden of the agreement is not symmetrically shared. European exporters gain preferential access to the Mexican market in sectors that generate above-average scale pressure on emissions, while Mexican exporters to the EU expand disproportionately in cleaner assembled manufacturing activities.

This asymmetry is partly a consequence of the tariff structure of the agreement and partly a reflection of the two economies' different positions in global value chains. From a policy perspective, it suggests that a purely bilateral lens on environmental effects may be insufficient. The carbon consequences of trade liberalisation are distributed unevenly across directions, sectors, and partners, and evaluating them at the aggregate level risks concealing that distribution.

Finally, the finding that third-country exporters were not displaced from EU and Mexican markets carries an environmental implication that extends beyond the EU-Mexico case. The spillover effects on both trade and emissions are positive and nearproportional, indicating that the agreement neither diverted production toward third countries nor concentrated emissions among less regulated producers outside the preferential zone.

These results are directly relevant for the current debate around CBAM. If trade agreements systematically expand rather than divert trade, the concern that preferential liberalisation shifts emissions to less regulated third-country producers may be less warranted than aggregate theory would suggest, though generalisation to other agreements requires further empirical verification. The methodological approach developed here, which identifies spillover effects separately from bilateral trade creation and maps both into embodied emissions, provides a direct empirical basis for that assessment and could be applied to other agreements where carbon leakage through trade diversion is a policy concern.

5.4 Limitations and directions for future research

Several limitations of the empirical design deserve explicit acknowledgement, as each also points toward productive directions for future work.

The most fundamental constraint is the sample period. The analysis covers 1995 to 2005, providing five pre-treatment and six post-treatment years around the FTA's entry into force in 2000. This window was chosen deliberately: extending the sample further risks introducing confounding factors that would compromise the identification of the FTA's specific impact, including additional trade agreements concluded by the EU and Mexico with third parties, structural shifts in global value chains following China's WTO accession in 2001, and the macroeconomic disruption of the 2008 financial crisis. Within the 1995 to 2005 window, these threats to identification are more tractable, and the FTA treatment can more credibly be isolated from concurrent developments.

The cost of this choice is that the sample is too short to capture longer-run dynamics in technology diffusion, supply chain reorganisation, and regulatory convergence that theory suggests materialise over extended time horizons. The sharp acceleration of the technique effect in 2004 and 2005, particularly along the EU-to-Mexico margin, is suggestive of dynamics that may have continued beyond the window. Future work that carefully accounts for these confounders, perhaps through event-study designs with year-specific treatment indicators or by explicitly controlling for post-2000 liberalisation among third parties, could extend the horizon while preserving credible identification.

A related limitation concerns the treatment of the technique effect as a residual. Because FTA-attributable changes in within-sector emission intensities cannot be directly identified within the bilateral gravity framework (emission intensities do not vary bilaterally), the technique component is inferred as the difference between total FTA-attributable emissions and the scale-composition counterfactual. This means it absorbs not only genuine changes in production technology and energy mix but also measurement error in the underlying trade and emissions data, model misspecification in the gravity estimates, and any compositional shifts within sectors that the sectoral classification does not resolve. Disentangling these sources requires either finer sectoral disaggregation than the OECD ICIO classification currently provides, or direct data on within-sector emission intensity changes at the country level. Both are areas where data availability is improving, and future research that can separate genuine technique effects from residual noise would substantially sharpen the environmental interpretation of decomposition results.

The identification strategy (Section 3.3) relies on a DiD logic that assumes parallel trends between treated and untreated country pairs in the absence of the FTA. With only five pre-treatment years and a single post-treatment indicator, the empirical design has limited capacity to formally test this assumption or to rule out anticipation effects. Firms may have begun adjusting trade patterns in response to the agreement's negotiation well before its formal entry into force in 2000, and the relatively short pre-period does not allow such dynamics to be isolated. Future work using event-study specifications with year-by-year treatment indicators, rather than a single post-treatment dummy, would allow a more rigorous assessment of pre-trends and of the precise timing of the trade and emissions response.

A further limitation concerns the scope of the environmental indicator. The analysis focuses exclusively on CO_2 emissions embodied in exports, which is the most tractable and consistently measured indicator across the OECD ICIO framework. This excludes other environmentally relevant dimensions of trade liberalisation, such as land use change, water consumption, local air pollutants, and biodiversity pressure. The Ecorys (2017) evaluation identifies each of these as potentially affected by the EU-Mexico agreement, although the estimated effects remain relatively limited. Extending the embodied-emissions framework to other environmental indicators as consistent multi-country data become available would provide a more complete assessment of the environmental footprint of trade agreements and allow researchers to determine whether the compositional adjustment documented for CO_2 extends to other pollutants or is specific to carbon.

The spillover coefficient captures the aggregate response of third-country exports to the EU and Mexican markets, but it pools several distinct mechanisms that the present design cannot disentangle. A complete analysis of the third-country dimension would need to account for general-equilibrium demand spillovers and vertical integration through global value chains, where intermediate inputs from third countries scale up mechanically alongside bilateral final-goods trade. It would also need to consider sector- and partner-specific tariff escalation, differences in the regulatory environments of individual third-country exporters, and the parallel proliferation of other preferential agreements involving the same countries during the sample period. These mechanisms can move in opposite directions and operate at different time horizons, so a single dummy that pools all third-country exporters provides only a first-order summary of the net effect.

The European Commission's Impact Assessment (2015) and the Ecorys (2017) ex post evaluation likewise treat third-country effects in aggregated form, using grouped regional categories rather than partner-specific identification. A deeper investigation of these mechanisms, including partner-specific decomposition of the spillover and the role of value-chain integration with non-FTA exporters, lies beyond the scope of this thesis but represents a natural and policy-relevant extension. The bilateral structure of the OECD ICIO data can support such an extension once it is combined with detailed tariff data and information on parallel agreements at the partner level.

From a broader perspective, the analysis is specific to a first-generation, tariff-focused agreement between partners at different income levels and with no meaningful environmental provisions. The EU-Mexico case may therefore not be representative of the environmental consequences of newer-generation agreements that include regulatory alignment, investment provisions, and explicit sustainability chapters. Applying the same integrated gravity-decomposition framework to agreements such as CETA, the EU-Japan EPA, or the modernised EU-Mexico agreement once sufficient post-implementation data become available would allow systematic comparison of how the depth and environmental architecture of trade agreements shapes the scale, composition, and technique channels through which liberalisation affects embodied emissions.

That comparative agenda, linking agreement design to environmental outcomes through observed trade data rather than simulation, is the direct continuation of what this thesis began. The framework is in place. The question of whether environmental provisions in newer-generation agreements translate into better outcomes is now answerable with the tools developed here.

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Appendix

A.1 Sector classification and interpretation

The OECD ICIO database distinguishes production activities using aggregated sector codes, which combine industries with similar production technologies.

Table 4: Sector classification (ICIO / TiVA mapping)

- **Primary sectors (raw materials and extraction)**
  - *01T02*: Agriculture, forestry and fishing
  - *03*: Fishing and aquaculture
  - *05T06*: Mining and quarrying
  - *07T08*: Mining support activities
  - *09*: Other extraction activities
- **Energy and heavy industry (high carbon intensity)**
  - *19*: Coke and refined petroleum products
  - *20*: Chemicals and chemical products
  - *23*: Other non-metallic mineral products (e.g. cement, glass)
  - *24*: Basic metals
  - *35*: Electricity, gas, steam and air conditioning supply
- **Manufacturing sectors (heterogeneous carbon intensity)**
  - *10T12*: Food products, beverages and tobacco
  - *13T15*: Textiles, wearing apparel and leather
  - *16*: Wood and products of wood
  - *17T18*: Paper, printing and reproduction
  - *21*: Pharmaceuticals
  - *22*: Rubber and plastics
  - *25*: Fabricated metal products
  - *26-28*: Machinery and equipment (electrical and non-electrical)
  - *29-30*: Transport equipment (motor vehicles, other transport)
  - *31T33*: Other manufacturing
- **Construction and utilities**
  - *36T39*: Water supply, sewerage and waste management
  - *41T43*: Construction
- **Trade and transport sectors**
  - *45T47*: Wholesale and retail trade
  - *49-53*: Transport and storage (land, water, air, warehousing, postal) → *50*: Water transport & *49*: Land transport and transport via pipelines
- **Service sectors (low direct emissions)**
  - *55T56*: Accommodation and food services
  - *58T60*: Publishing, audiovisual and broadcasting
  - *61*: Telecommunications
  - *62T63*: IT and information services
  - *64T66*: Financial services
  - *68*: Real estate
  - *69T75*: Professional, scientific and technical activities
  - *77T82*: Administrative and support services
  - *84*: Public administration
  - *85*: Education
  - *86T88*: Health and social work
  - *90T93*: Arts, entertainment and recreation
  - *94T96*: Other services
  - *97T98*: Activities of households

A.2 Decomposition results

This appendix presents the numerical decomposition results that underpin the discussion in Section 4.5. Table 5 reports the pooled EU-Mexico bilateral channel; Tables 6 and 7 report the directional decompositions for EU-to-Mexico and Mexico-to-EU flows respectively. All values are expressed in million tonnes of CO_2 relative to the 1995 baseline, with percentage figures relative to base-year treated emissions in brackets.

Table 5: Scale-composition-technique decomposition of FTA-attributable embodied CO_2 emissions

Year	Total ΔE	Scale	Composition	Technique	Total (% base)
2000	**0.527**	1.185	-0.401	-0.257	15.222
2001	**0.503**	1.238	-0.463	-0.272	14.539
2002	**0.500**	1.313	-0.509	-0.304	14.450
2003	**0.584**	1.406	-0.594	-0.227	16.885
2004	**0.560**	1.630	-0.558	-0.513	16.181
2005	**0.658**	1.773	-0.469	-0.646	19.014

Note: All values in model-implied units. Baseline intensities fixed at 1995. Total (% base) = total FTA-attributable emissions change as % of base-year (1995) treated emissions. Identity: Scale + Composition + Technique = Total ΔE.

Table 6: Scale-composition-technique decomposition EU to Mexico channel, 2000-2005

Year	Total ΔE	Scale	Composition	Technique	Total (% base)
2000	**0.401**	0.722	-0.193	-0.127	25.791
2001	**0.415**	0.770	-0.283	-0.072	26.698
2002	**0.406**	0.827	-0.306	-0.115	26.111
2003	**0.380**	0.879	-0.319	-0.180	24.427
2004	**0.379**	1.016	-0.261	-0.376	24.369
2005	**0.390**	1.096	-0.123	-0.583	25.070

Note: All values in model-implied units. Baseline intensities fixed at 1995. Total (% base) = total FTA-attributable emissions change as % of base-year (1995) treated emissions. Identity: Scale + Composition + Technique = Total ΔE.

Table 7: Scale-composition-technique decomposition Mexico to EU channel, 2000-2005

Year	Total ΔE	Scale	Composition	Technique	Total (% base)
2000	**0.147**	0.339	-0.202	0.009	7.707
2001	**0.121**	0.337	-0.192	-0.024	6.336
2002	**0.124**	0.345	-0.204	-0.017	6.507
2003	**0.202**	0.377	-0.224	0.049	10.630
2004	**0.185**	0.440	-0.255	0.000	9.705
2005	**0.251**	0.489	-0.312	0.074	13.184

Note: All values in model-implied units. Baseline intensities fixed at 1995. Total (% base) = total FTA-attributable emissions change as % of base-year (1995) treated emissions. Identity: Scale + Composition + Technique = Total ΔE.

A.3 Decomposition results for third-country channels

Figure 13: Relative CO_2 decomposition for Mexico-Third country trade (% of base-year emissions)

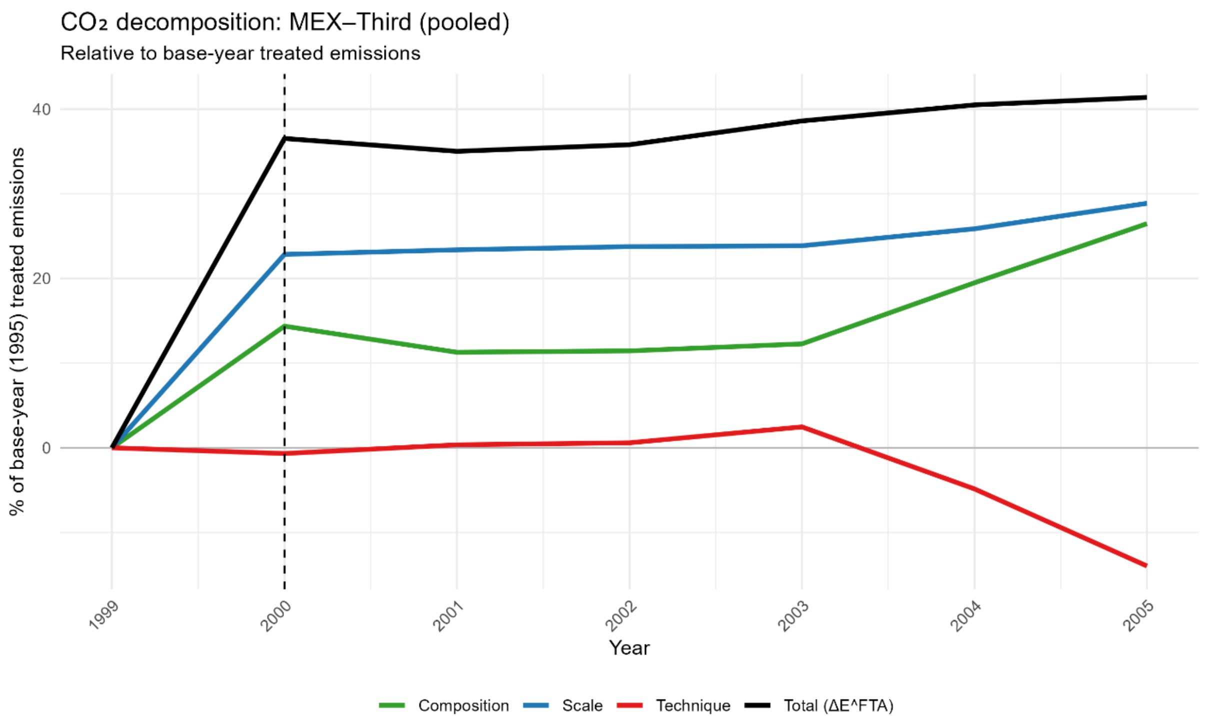


Figure 14: FTA-attributable CO_2 decomposition for Mexico-Third country trade (pooled)

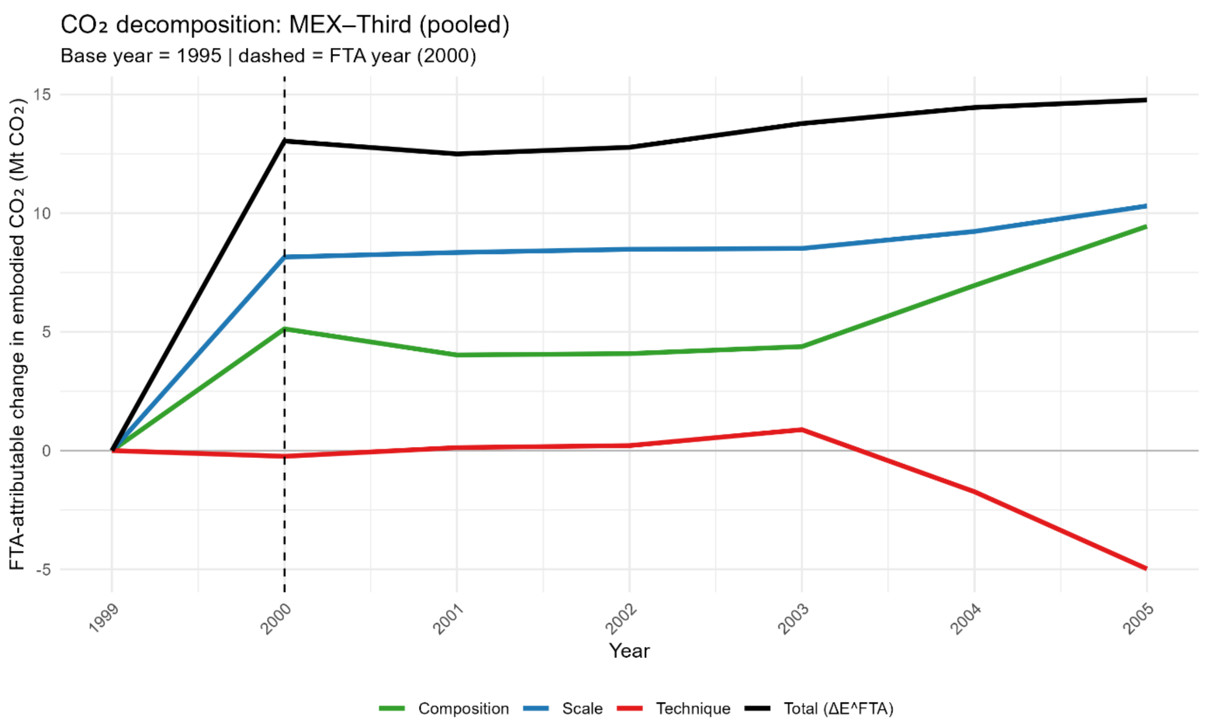


Figure 15: FTA-attributable CO_2 decomposition for EU-Third country trade (pooled)

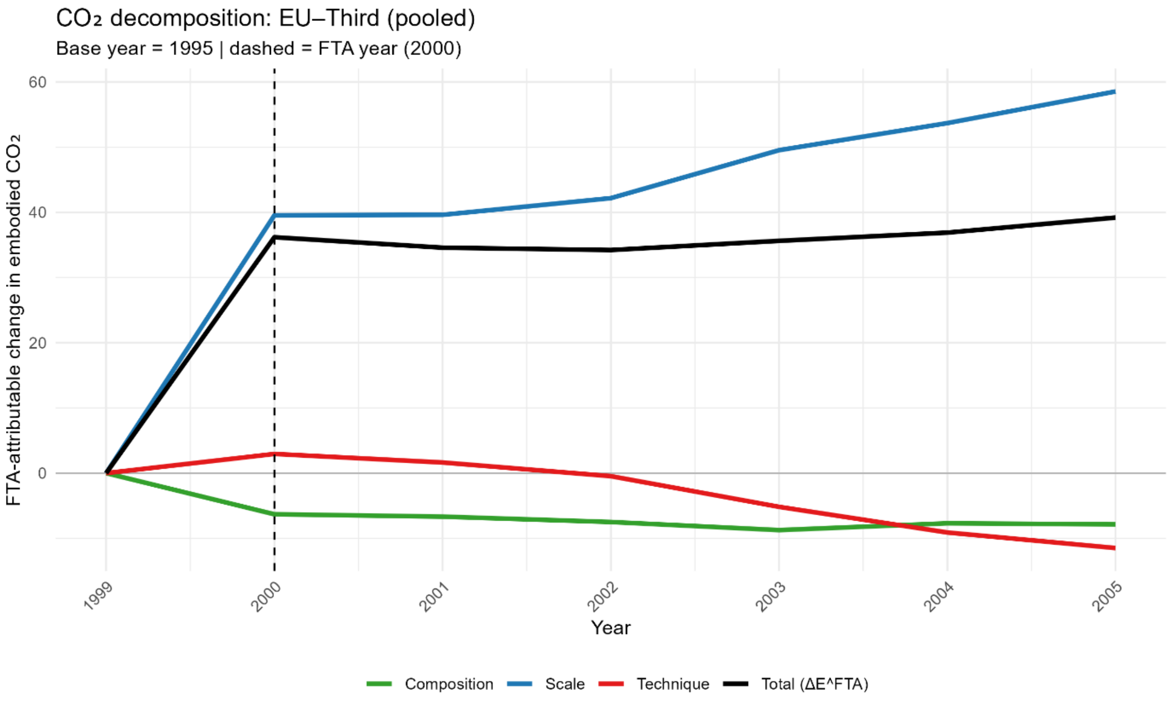
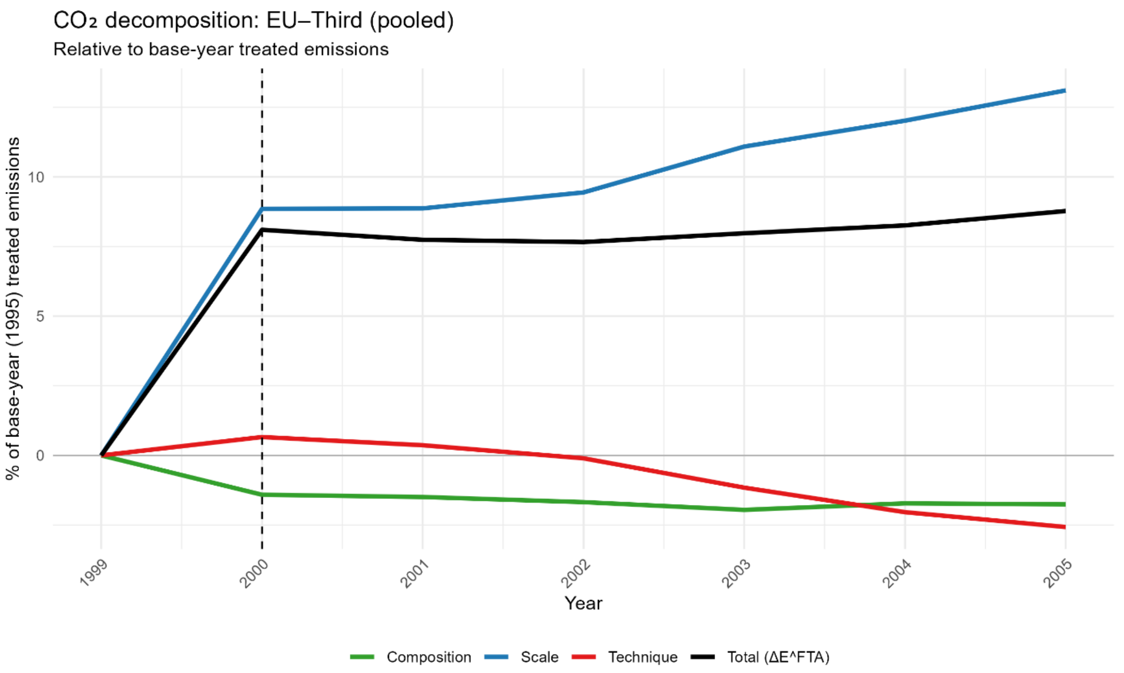


Figure 16: Relative CO_2 decomposition for EU-Third country trade (% of base-year emissions)



Note: For completeness, the scale-composition-technique decomposition is also implemented for the two third-country channels: EU-Third (third-country exports to and from the European Union, excluding Mexico) and Mexico-Third (third-country exports to and from Mexico, excluding the EU). These channels capture the broader environmental footprint of trade reallocation involving partners not directly party to the EU-Mexico FTA, and are the empirical counterpart to the spillover coefficient identified in the gravity estimations of Sections 4.3 and 4.4. In the absolute figures (14 and 15), values are expressed in million tonnes of CO_2 relative to the 1995 baseline; the relative figures (13 and 16) are expressed as a percentage of base-year treated emissions.

A.4 Robustness checks

This appendix presents three robustness checks on the main gravity specifications reported in Tables 2 and 3. Each check varies one element of the baseline specification while holding all other components constant.

Specification (2): Extended sample. This specification extends the analytical sample from 1995-2005 to 1995-2010, adding five additional post-treatment years. The EU-Mexico FTA coefficient rises from 0.234 to 0.356 for trade and from 0.164 to 0.269 for embodied CO_2, while the spillover coefficients increase modestly from 0.191 to 0.210 (trade) and from 0.161 to 0.203 (CO_2). The growth in coefficient magnitude over the extended period is consistent with cumulative FTA effects building up over time, and all coefficients retain their statistical significance and sign.

Specification (3): Excluding China. This specification excludes China as a trading partner from the analytical sample. China's accession to the WTO in December 2001 represents a major concurrent change in global trade patterns during the analysis window and could potentially confound the identification of FTA-attributable effects. Excluding China from both the origin and destination dimensions yields EU-Mexico FTA coefficients of 0.240 for trade and 0.170 for embodied CO_2, and spillover coefficients of 0.167 and 0.135 respectively. The EU-Mexico coefficients are virtually unchanged from the main specification, while the spillover coefficients decline modestly, consistent with China's role as a significant third-country trading partner over this period. The qualitative stability of the main estimates indicates that the FTA effects identified in the baseline specification are not driven by the structural rise of Chinese trade.

Specification (4): Adding a PTA post-interaction. This specification adds a post-treatment interaction for the other-PTA control while retaining the level effect. The main coefficients of interest move only modestly (EU-Mexico from 0.234 to 0.257 for trade and from 0.164 to 0.221 for emissions; spillover from 0.191 to 0.164 for trade and from 0.161 to 0.139 for emissions). The level effect of other PTAs turns insignificant while the post-interaction is significant, reflecting that most within-pair variation in PTA status occurred after 2000 and is therefore captured by the post-interaction rather than the level term. The stability of the main coefficients supports the baseline modelling choice of retaining only the level term, which keeps the post-treatment variation reserved for the EU-Mexico and spillover dummies that are the focus of identification.

Table 8: Robustness checks - bilateral trade flows, 1995-2005

(2)**Extended sample**

```
                                                         model
Dependent Var.:                                         values

EU-MEX FTA (post × EU-MEX)                        0.356***
                                                    (0.061)
Spillover: Third → EU or MEX (post × spill)         0.210***
                                                    (0.051)
Other PTAs (active in year t)                       0.118***
                                                    (0.028)
Fixed-Effects:                                    ---------
exp_sec_year                                           Yes
imp_sec_year                                           Yes
pair_sec                                               Yes
________________________________________       _________
S.E.: Clustered                             by: pair. & year
Observations                                     2,987,487
Pseudo R2                                          0.99824
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

(3)**Excluding China**

```
                                                         model
Dependent Var.:                                         values

EU-MEX FTA (post × EU-MEX)                        0.240***
                                                    (0.056)
Spillover: Third → EU or MEX (post × spill)         0.167***
                                                    (0.035)
Other PTAs (active in year t)                       0.054*
                                                    (0.025)
Fixed-Effects:                                    ---------
exp_sec_year                                           Yes
imp_sec_year                                           Yes
pair_sec                                               Yes
________________________________________       _________
S.E.: Clustered                             by: pair. & year
Observations                                     1,985,346
Pseudo R2                                          0.99863
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

(4)**PTA post-interaction**

Dependent Var.:	model values
EU-MEX FTA (post × EU-MEX)	0.257***
	(0.058)
Spillover: Third → EU or MEX (post × spill)	0.164***
	(0.034)
post x Other PTAs (active in year t)	0.091***
	(0.018)
Other PTAs (active in year t)	0.003
	(0.035)
Fixed-Effects:	---------
exp_sec_year	Yes
imp_sec_year	Yes
pair_sec	Yes
S.E.: Clustered	by: pair. & year
Observations	2,045,879
Pseudo R2	0.99852

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

*Note: PPML estimates of FTA-attributable changes in bilateral trade flows under alternative specifications. Specification (2) extends the analytical sample from 1995-2005 to 1995-2010. Specification (3) excludes all observations where China is either origin or destination, controlling for China's 2001 WTO accession as a concurrent shock. Specification (4) adds a post-treatment interaction term for the other-PTA control. All specifications include exporter-sector-year, importer-sector-year, and pair-sector fixed effects. Standard errors clustered at the pair-sector and year level are reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05, · p<0.1.*

Table 9: Robustness checks - embodied CO_2, 1995-2005

(2) Extended sample

	model
Dependent Var.:	co2_in_exports
EU-MEX FTA (post × EU-MEX)	0.269**
	(0.089)
Spillover: Third → EU or MEX (post × spill)	0.203***
	(0.057)
Other PTAs (active in year t)	0.212***
	(0.046)
Fixed-Effects:	--------------
exp_sec_year	Yes
imp_sec_year	Yes
pair_sec	Yes
S.E.: Clustered	by: pair. & year
Observations	2,874,203
Pseudo R2	0.95616

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(3) Excluding China

	model
Dependent Var.:	co2_in_exports
EU-MEX FTA (post × EU-MEX)	0.170*
	(0.070)
Spillover: Third → EU or MEX (post × spill)	0.135***
	(0.034)
Other PTAs (active in year t)	0.094*
	(0.047)
Fixed-Effects:	--------------
exp_sec_year	Yes
imp_sec_year	Yes
pair_sec	Yes
S.E.: Clustered	by: pair. & year
Observations	1,896,600
Pseudo R2	0.94731

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(4)**PTA post-interaction**

	model
Dependent Var.:	co2_in_exports
EU-MEX FTA (post × EU-MEX)	0.221**
	(0.073)
Spillover: Third → EU or MEX (post × spill)	0.139***
	(0.038)
post x Other PTAs (active in year t)	0.146***
	(0.029)
Other PTAs (active in year t)	0.034
	(0.053)
Fixed-Effects:	--------------
exp_sec_year	Yes
imp_sec_year	Yes
pair_sec	Yes
S.E.: Clustered	by: pair. & year
Observations	1,955,750
Pseudo R2	0.95441

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Note: PPML estimates of FTA-attributable changes in embodied CO_2 emissions in exports (measured in million tonnes) under alternative specifications. Specification (2) extends the analytical sample from 1995-2005 to 1995-2010. Specification (3) excludes all observations where China is either origin or destination, controlling for China's 2001 WTO accession as a concurrent shock. Specification (4) adds a post-treatment interaction term for the other-PTA control. All specifications include exporter-sector-year, importer-sector-year, and pair-sector fixed effects. Standard errors clustered at the pair-sector and year level are reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05, · p<0.1.