



Interregional trade estimation as a case for economic integration

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ABSTRACT

This paper explores the estimation of interregional trade as a lens through which to assess the broader dynamics of economic integration, with a particular emphasis on the persistent "border effect" in the European Union (EU). Although regional integration is intended to foster seamless economic flows through policy convergence and infrastructural alignment, empirical evidence reveals significant barriers to cross-border trade. These frictions (both tangible and intangible) challenge the assumption of a borderless economy within integrated regions. Through a systematic literature review guided by the PRISMA methodology, the study examines the evolution of trade estimation techniques, focusing on the gravity model as the dominant analytical framework. The review highlights key methodological innovations, including hybrid gravity-input-output models, RAS calibration, and spatial econometrics, as well as sectoral and regional applications that expose asymmetries in trade flows. By synthesizing findings from peer-reviewed sources and academic research, the paper reveals the multidimensional nature of border effects and the uneven outcomes of integration policies. The analysis is complemented by references to grey literature, mainly policy documents, allowing to set the societal relevance of the research. It concludes that while gravity models remain central to trade analysis, their future relevance depends on incorporating behavioural, infrastructural, governance and political dimensions. This work contributes to ongoing academic and policy debates by advocating for a more nuanced, interdisciplinary approach to understanding economic integration in an increasingly fragmented yet interconnected world.

1. Introduction

In an era marked by increasingly interdependent economies, at times where geopolitical tensions are harming international cohesion, economic integration has emerged as a central theme in both academic discourse and policy agendas. Economic integration refers to the process by which separate national or regional economies become more interconnected through the reduction of barriers to trade, investment, and the movement of labour and capital (Balassa, 1961). This process can occur at multiple levels, varying from bilateral agreements to complex multilateral systems such as the European Union (EU), which not only reduce tariffs and quotas but also harmonise policies and infrastructures (Fontagné and Freudenberg, 1997; Ecochard et al., 2006; Egan & Guimaraes, 2017; Beyer et al., 2025). The economic logic underlying

integration rests on the expectation that closer ties will enhance efficiency through a reallocation of resources, which in turn stimulates overall economic growth (Walz, 1998). However, its actual outcomes vary significantly depending on geographical, institutional and infrastructural conditions (Chakraborty et al., 2017; Camera et al., 2023; Nach and Ncwadi, 2024).

A critical dimension of this broader phenomenon is regional economic integration, which examines how neighbouring or proximate economies overcome barriers created by geography, poor infrastructure and inefficient policies that are an impediment to economic growth (World Bank). While the theoretical benefits of regional integration such as scale economies, reduced transaction costs, enhanced competitiveness, political agreements, and international alignment are well-documented (Grimwade, 2013; Helpman, 1981; Helpman and

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Krugman, 1985; Lucas, 1988, Krugman, 1991), the empirical literature reveals a more nuanced picture. Studies show that integration can also generate asymmetrical effects across countries, sectors, and social groups. Indeed, integrated economies benefit from increased trade, higher efficiency and more opportunities but these gains often come at a cost, including structural adjustments, sectoral dependence, regional imbalances and labour market dislocations (Büttner and Rincke, 2004; Colantone et al., 2015; Vedres and Nordlund, 2018; Bekbolotova et al., 2025). These factors which frequently affect the population unevenly can offset or complicate the evaluation of aggregate outcomes. Therefore, this integration process is far from frictionless, as its results are shaped by pre-existing inequalities and the diverse capacity of economies and societies to adapt.

Within this context, understanding the role of borders in shaping economic interactions remains one of the most persistent and paradoxical challenges. Borders are not merely lines on a map but dynamic structures that influence the flow of goods, services, people, and ideas. These boundaries can create both opportunities and constraints, preserving unique regional identities and facilitating cross-border cooperation, while also posing challenges to integration and cohesion (Brunet-Jailly, 2011; Radil and Ptak, 2024). One of the cumulative impacts of these frictions is captured by the so-called “border effect”, which refers to the quantifiable reduction in the exchange of goods and services observed across national and regional boundaries, even in contexts of formal integration and policy convergence (McCallum, 1995; Anderson and van Wincoop, 2003; Spolaore and Wacziarg, 2005; Nitsch and Wolf, 2013; Carter and Poast, 2020). This is also formally acknowledged by the European Commission (European Commission 2017), that estimates its negative impact as 8.8 % of total GDP produced in land border regions”, but having significantly differentiated impact across Europe (European Commission 2017a), based on Camagni et al. (2017). This effect arises not only from tangible barriers such as geographical features, infrastructure gaps, customs procedures, regulatory and legal differences, but also from less quantifiable dimensions, including political friction, informational asymmetries, cultural and historical legacies (Chen, 2024; Nordås and Kox, 2009; Fidrmuc and Hainz, 2013). Even within highly integrated blocs like the EU, intra-national trade often remains more robust than cross-border exchange, suggesting that full integration is far from being reached. Recent advancements, particularly in gravity modelling, have attempted to better disentangle these effects, more precisely, highlighting how spatial, sectoral, economic and institutional factors shape the enduring significance of borders in a supposedly borderless economy.

This paper engages with the literature on interregional trade estimation as a lens through which to assess the broader dimension of economic integration, with a particular focus on the border effect in regional contexts. The conduction of a systematic literature review guided by the PRISMA methodology has allowed to examine the conceptual, methodological, and empirical evolution of how interregional trade is understood and estimated, especially within the EU framework. The review critically evaluates gravity models as dominant tools for trade estimation and explores their adaptation to regional trade scenarios where direct data is often unavailable. It also interrogates the effectiveness of EU policies in reducing border-related frictions and promoting cohesive economic development across regions.

The paper is structured as follows. Following this introduction, the methodology section outlines the systematic review process, detailing the criteria for literature selection and thematic categorisation. The results section presents key findings from the selected studies, organised by themes such as model innovations, policy impacts, sectoral applications, and border dynamics. The discussion section offers a critical synthesis, identifying gaps, emerging trends, and future research directions. Finally, the conclusion reflects on the implications of the findings for both academic inquiry and policy design in the realm of regional economic integration.

2. Methodology

The methodology employed in this study adheres to a mixed-methods approach guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) protocol (Page et al., 2021). The protocol is adapted to align with the current study’s research questions and objectives (see Table 1–4). PRISMA encompasses a three-step process: Identification, Screening, Eligibility and Inclusion.

The rationale behind choosing the PRISMA methodology stems from the need for a structured and reproducible approach to synthesising academic knowledge. The PRISMA protocol was chosen due to its ability to systematically identify, screen, and assess the literature, ensuring a comprehensive and methodical analysis. This facilitates identifying research gaps and scientific debate while maintaining a high level of scholarly rigor. Its adaptability allows the study to align with specific research objectives, ensuring relevance and precision in exploring the strategic landscape of inter-regional trade.

Because of its extensive database and sophisticated search features, Scopus was selected as the main search engine. To ensure a comprehensive collection of pertinent publications, word combinations in titles, author keywords, and abstracts are explored using Boolean and wildcard searches. The keywords used on Scopus were the following: (Inter-regional) OR (Regions) AND (Trade estimation) AND (European union) OR (EU) OR (Gravity model) OR (Constrained gravity model) OR (RAS).

The first step was to define the domain, with the focus on inter-regional trade, border effects and gravity model, within the EU framework as discussed in academic literature. This identification establishes parameters and directs the investigation towards facets of inter-regional trade, setting the stage for the study. The purpose of the research question, which guides the inquiry, is to reveal the breadth and depth of past scientific studies conducted in this field.

The screening stage selected academic articles, books, conference proceedings and other scholarly outputs. Searches covered the period 2000–2025 and returned 186 records for initial screening. We limit the sample to publications from 2000 onward to focus on the post-single-market era and methodological innovations that followed EU deepening and the introduction of the euro. However, for the introduction of each methodology we included renowned studies to settle the pace for the analysis.

In order to facilitate the identification of themes and patterns in the literature, the gathered articles are categorised based on relevant topics during the organisation stage. This methodology enables a methodical analysis and juxtaposition of study outcomes. During the screening and purification stage, titles and abstracts are examined to ensure that the papers are directly related to the study issue. After the screening phase, 91 documents are kept out of the original pool of 186 results, demonstrating the elimination of documents that were judged unnecessary or redundant. These exclusions primarily concerned studies that fell outside the research scope, lacked empirical analysis or methodological discussion, or duplicated findings already covered in other included sources. The final selection retained only those works that provided original, peer-reviewed contributions directly relevant to interregional trade estimation, the gravity model, or border effects. The full screening and selection process is summarised in Fig. 1, following the PRISMA protocol. At the end of the screening phase, a total of 49 documents were kept for the final analysis.

During the evaluation phase, all retained documents have been thoroughly studied to extract important information and insights about inter-regional trade and economic integration. This analysis points out gaps in the literature and makes recommendations for possible future study topics. The review procedure follows established standards for academic reporting, clearly and methodically presenting the results and analysis. Even while the review is undertaken independently without the aid of outside financing, it does admit several limitations, such as the fact that the data source is limited to Scopus. This methodical methodology guarantees a thorough and reliable analysis of the literature about

Table 1

Summary of Methodological Innovations. Source: Authors' own elaboration.

Key Literature	Strand	Core Idea	Strengths	Limitations
Ravenstein (1885); Isard (1954); Tinbergen (1962); Pöyhönen (1963); Evenett & Keller (2002); Caponai (2023)	Classical / gravity origins	Bilateral flows explained by partner economic size and geographic distance (Newtonian analogy). Empirical reduced-form gravity.	Simple, intuitive baseline; easy to communicate.	Misleading with heteroskedasticity and zeros; lacks theoretical micro-foundation.
Eaton and Kortum (2002); Melitz (2003); Chaney (2008); Arkolakis et al. (2008); Melitz and Ottaviano (2008); Helpman et al. (2008)	Theoretical micro-foundations / heterogeneous firms	Introduce firm heterogeneity, selection into export markets, and general-equilibrium implications for intensive/extensive margins. Justifies modelling zeros and heterogeneous bilateral responses.	Provides causal logic for margins and selection; supports counterfactual and general-equilibrium analysis.	High model complexity; strong parametric assumptions; data-hungry for firm-level heterogeneity.
Anderson and van Wincoop (2003); Anderson & Yotov (2010); Redding and Venables (2004); Fally (2015)	Multilateral-resistance / structural gravity	Correct bias from ignoring each partner's overall market accessibility; structural form enforcing general-equilibrium consistency via multilateral-resistance terms.	Theoretically consistent for counterfactuals; controls market access heterogeneity.	Requires careful fixed-effect specification; computational burden with many fixed effects.
Santos Silva and Tenreiro (2006), (2011); Helpman et al. (2008); Proenca et al. (2015)	Estimator robustness / handling zeros and heteroskedasticity	Showed log-OLS is inconsistent under heteroskedasticity and with zeros; explicitly model selection from market entry; capture heterogeneity.	Robust to zeros and many data idiosyncrasies; flexible for short panels or complex heterogeneity.	Requires correctly specified conditional means; sensitive to functional form and sample-selection assumptions; complex interpretation.
Kali and Reyes (2007); Dueñas & Fagiolo (2011); Hübner (2016)	Network & spatial topologies	Network centrality and spatial dependence capture systemic spillovers and endogenous interdependence.	Captures spillovers, indirect effects, system-level dependencies.	Endogeneity of network position; identification challenges; heavy computation.
Stack (2009); Head and Mayer (2014); Fally (2015)	Comparative benchmarking and integrative synthesis	Systematic comparison of specifications and estimators to assess sensitivity of inference to estimator or fixed-effects choices.	Reveals estimator-dependent inference; promotes best-practice checklists.	Requires harmonization for fair comparison; results can be context-dependent.

Table 2

Summary of Complementary Approaches. Source: Authors' own elaboration.

Key Literature	Methodological Strand	Core Idea	Strengths	Limitations
Leontief (1936); Isard (1954)	Leontief input–output accounting	Treat the economy as a system of interlinked industries and regions, using linear equations to trace interdependencies.	Provides transparent accounting structure; high internal validity.	Requires extensive survey data; costly and time-intensive; no behavioral dimension.
Flegg et al. (1995); Flegg and Webber (1997)	Non-survey I–O regionalisation (Location Quotients, FLQ)	Approximate regional I–O coefficients using employment/output shares; FLQ adjusts for regional size bias.	Low data requirements; practical for constructing regional tables.	Size bias and industry bias, especially in small regions; sensitive to scaling parameters.
Canning and Wang (2005); Llano (2004); Llano et al. (2010); Miller and Blair (2009)	Multiregional Input–Output (MRIO) and cross-entropy methods	Reconcile priors with observed aggregates to produce balanced MRIO tables.	Enforces interregional and national consistency.	Sensitive to priors; Many admissible solutions; Can hide behavioural patterns.
Wilson (1971)	Constrained gravity models	Estimate missing bilateral flows using gravity logic (economic mass and distance) while constraining to known totals (singly or doubly constrained).	Combines behavioural plausibility with aggregate consistency; interpretable in economic terms.	Accuracy depends on quality of constraints and cost function; may yield multiple feasible solutions.
Sargento et al. (2003), (2012); Ferreira (2008); Fournier Gabela (2020); Distefano et al. (2019); Patandianan and Shibusawa (2020); Cai (2023)	Hybrid gravity–RAS frameworks	Merge structural gravity with matrix balancing to estimate consistent interregional trade matrices in data-scarce contexts.	Ensures exact correspondence with observed totals; simple and numerically stable.	High sensitivity to prior/cost calibration; requires careful benchmarking.

EU macro-regional policies.

To clarify the selection process, during the screening stage, we excluded studies that did not explicitly address interregional trade estimation, gravity-based approaches, or border effects within the European context. Publications were also removed when they were conceptually overlapping or focused on unrelated macroeconomic or international trade topics. The reduction from 186 to 91 reflects this first-stage exclusion of irrelevant or redundant material. The subsequent narrowing from 91 to 49 documents corresponds to the eligibility and inclusion stages, where only studies meeting the full set of relevance, methodological transparency, and peer-reviewed quality criteria were retained for final analysis. A detailed record of inclusion and exclusion steps is provided in Fig. 1 following the PRISMA framework.

The final set of papers deliberately focuses on interregional trade studies, that is, analyses of trade flows within countries or between

subnational regions across borders, typically within integrated areas such as the European Union. While a few international trade studies are cited for their foundational theoretical or methodological contributions (for example, early developments in the gravity model), only those papers that apply or adapt these frameworks to the estimation of interregional trade or border effects were included in the systematic review. This distinction ensures that the synthesis remains centered on interregional dynamics while still grounding the discussion in the broader evolution of trade modelling.

One limitation of this study is the exclusive use of Scopus as the primary source for the literature review. The authors fully acknowledge that there are numerous other sources, including repositories of policy papers and research reports provided by European Union institutions and agencies (and other international organisations), which offer valuable insights into inter-regional trade and related themes. However, the

Table 3

Summary of Regional Studies. Source: Authors' own elaboration.

Key Literature	Methodological Strand	Core Idea	Findings
Mayer, Vicard and Zignago (2019); Camarero et al. (2013); Glick (2017); Bun and Klaassen (2007); Gil-Pareja et al. (2005)	Structural gravity and counterfactual welfare simulations; long-run panel analysis.	Use estimated gravity elasticities to simulate counterfactuals and compute welfare gains from accession, EMU and deep integration.	Deep, enforceable integration raises bilateral trade and welfare on average; effects are heterogeneous in magnitude, timing, and across countries and sectors.
Stack and Pentecost (2011); Stack and Bliss (2020)	Identification and estimator diagnostics; FE richness; treatment of zeros.	Demonstrate sensitivity of integration estimates to estimator choice (PPML vs log-OLS), fixed-effects structure and treatment of zeros.	Rich FE structures and alternative estimators can materially change estimated "EU effect"; careful FE and estimator choice reduce bias and alter magnitudes.
Dragutinović-Mitrović and Bjelić (2015); Josić and Bašić (2021)	Event-study, staggered DiD, panel gravity (RE, PPML, Tobit); subnational panels.	Exploit temporal variation of agreements to identify trade-creation and diversion, and compare regional vs extra-regional flows.	CEFTA 2006 generated measurable intra-regional trade creation; EU accession often produced trade diversion and asymmetric impacts between incumbents and new members.
Leka et al. (2022); Leka and Jusufi (2024)	Institutional mediation; heterogeneous treatment analysis.	Emphasize role of institutional quality, political stability and competitiveness as mediators of agreement effectiveness.	Free trade arrangements often spur legal and institutional reform more than immediate export growth; SAAs produced limited sustained export growth in weak competitiveness settings, with incumbents benefiting more.
Paas and Tafenau (2005); Schlitte and Paas (2008)	Regional cluster and subnational gravity; panel and cluster analysis.	Analyse enlargement and cluster membership effects at subnational or regional cluster scale.	Enlargement and cluster membership deepen intra-regional ties; gains are spatially uneven and sector-specific, with core export-oriented areas capturing most benefits.

aim of this study is to provide an overview of the academic literature on the topic, focusing specifically on books and peer-reviewed research published in high-impact academic journals. Scopus was selected as it serves as a comprehensive and widely recognised database for high-level academic research, ensuring the scholarly rigor and credibility of the sources analysed. While the inclusion of additional sources could further

enrich the analysis, this study remains centred on academic discourse. Some complementary references are made to grey literature to illustrate the political and societal relevance of the research.

3. Results

Historically, the literature on trade, transports, and more specifically border effects has extensively relied on gravity models to analyse cross-border interactions as these models provide a simple framework to quantify the impact of different variables on bilateral flows. However, when focusing on interregional trade, where data are often incomplete or missing, traditional gravity approaches can fall short in accurately capturing these effects and typically require complementary methods to reconstruct trade flows and identify the persistence of spatial, institutional, or administrative frictions. For the scope of this review, we organise the following literature into four interrelated areas that reflect both methodological innovations and empirical applications in the study of regional trade and economic integration.

The thematic areas were identified through an iterative coding process during the review phase. Each selected paper was coded according to its main methodological focus, empirical application, and policy relevance. Coding yielded four broader thematic areas to avoid redundancy. The four themes capture the main directions in which this branch of the literature has evolved: (1) methodological innovations in gravity and trade estimation, (2) complementary approaches and regional trade estimation, (3) regional integration and sectoral applications, and (4) policy and structural dimensions of border effects. First, methodological innovations in gravity and trade estimation focus on refining estimation techniques, incorporating multilateral resistance terms, market structure, and spatial analysis improving calibration methods for more accurate predictions. Second, complementary approaches including input-output models, constrained gravity and gravity-RAS frameworks, have been developed to address missing or incomplete trade data, and to better capture the economic mechanism that underlie integration. Third, regional economic integration studies assess how trade policies, cross-borders agreements, border management, and infrastructure investments influence regional trade and regional GDP growth. These analyses provide quantitative insights into both direct and spillover effects of integration policies. Fourth, sector-specific applications extend the evaluation to different domains highlighting how different sectors respond to spatial and policy-related variables, such as technological and infrastructure-driven enhancements, skill distributions.

3.1. Methodological innovations in gravity and trade estimation

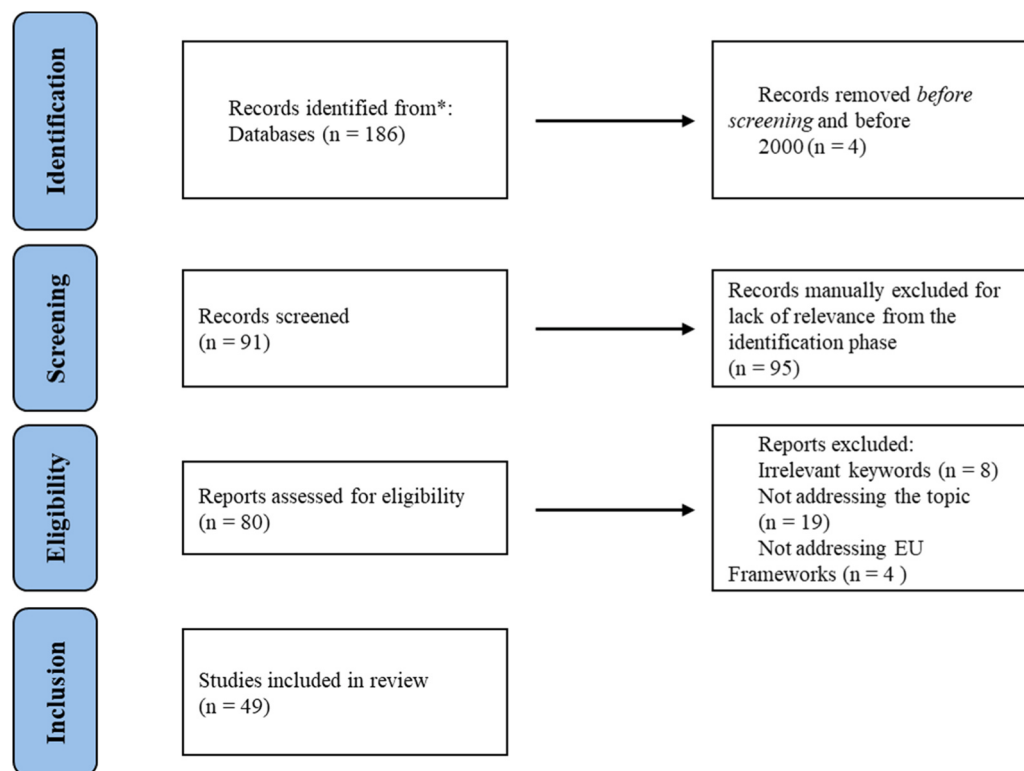
The gravity model has its intellectual roots in spatial economics. Early contributions (Ravenstein, 1885; Isard, 1954) used gravity-type formulations to describe flows of people, goods, and capital across space, drawing inspiration from Newtonian physics (Kabir et al., 2017). This analogy was first explicitly applied to trade in the sixties (Tinbergen, 1962; Pöyhönen, 1963; Evenett and Keller, 2002) when economists showed that bilateral flows could be explained by the economic size of partners and the geographical distance between them (Capoani, 2023). Despite its empirical success, the model initially lacked theoretical foundation. From the eighties onward, research has strengthened both its theoretical framework and econometric foundations (e.g., Anderson, 1979; Helpman and Krugman, 1985; Bergstrand, 1989; Krugman, 1991; Bergstrand, 1985).

Since the 2000s methodological progress has greatly reshaped both the theoretical and empirical practice of gravity modelling. One strand of the literature extended the microeconomic framework by incorporating firm heterogeneity, market structure, and self-selection into domestic and international markets. Building on the Ricardian approach linking geography and technology (Eaton and Kortum, 2002), Melitz (2003) and following (Chaney, 2008; Arkolakis et al., 2008; Melitz and

Table 4

Summary of Sector-Specific Applications. Source: Authors' own elaboration.

Key Literature	Methodological Strand	Core Idea	Findings
Marques and Metcalf (2005); Martínez-Zarzoso and Márquez-Ramos (2007)	Sectoral gravity and heterogeneous-firm extensions.	Technology and human capital shape sectoral responsiveness to trade costs and integration.	High-skill, capital-intensive sectors gain more from integration; elasticities to distance and policy vary by sector.
Bensassi et al. (2015); Shevtsova et al. (2025); Zaninovic et al. (2024); Barbero et al. (2021); Oesingmann (2022)	Augmented structural gravity; spatial econometrics.	Transport, ICT and border-efficiency infrastructures enter trade-cost functions and interact with geography.	Infrastructure raises exports/GDP but disproportionately benefits core regions; ICT and border efficiency support supply-chain trade and reduce peripherality.
Sarker and Jayasinghe (2007); Balogh and Leitão (2019); Houeninvo and Séedéji (2019)	Sectoral gravity for primary/agri-food sectors; regional panel analysis.	Agricultural/resource trade responds differently to integration, driven by comparative advantage, logistics and FDI.	Integration consolidates intra-EU agri-trade and may divert non-member flows; in low-income regions gains hinge on FDI, logistics and institutional complements.
Persyn and Torfs (2016); Padaki and Goel (2015); Riache et al. (2020); Chenaf-Nicet and Rougier (2016)	Heterogeneous-firm microfoundations integrated with gravity.	Firm heterogeneity and selection determine sectoral reallocation and elasticities to trade costs.	Firm entry/exit and selection amplify sectoral heterogeneity; GVC-ready firms and core regions capture outsized gains.

**Fig. 1.** Implementation of PRISMA methodology. Authors' elaboration based on [Page et al., \(2021\)](#).

Ottaviano, 2008; Helpman et al., 2008) formalised how productivity distributions, entry costs, trade barriers and market size can affect the extensive and intensive margin of trade. Although these studies primarily focused on the national level without considering subnational economic structures, they highlighted important patterns and characteristics that vary significantly across regions. This provided a theoretically grounded understanding of the determinants of bilateral trade flows. Notably, these models offered a justification for accounting for zero trade flows and for heterogeneity in bilateral responses to trade costs, implications that support specifying region-level variations across different products.

Alongside theoretical developments, researchers identified and addressed key econometric issues of early identifications. They moved the analysis from a primarily reduced-form empirical exercise to a plural set of tools that trade off theoretical structure, estimator robustness, and the ability to handle data idiosyncrasies. A first group of contributions tackled identification and general-equilibrium consistency. Anderson and van Wincoop (2003) demonstrated that neglecting

multilateral-resistance terms produces biased elasticities and proposed a structural formulation that properly accounts for each partner's overall market accessibility. Subsequent applied implementations operationalised these concepts using high-dimensional fixed effects to capture supply and market heterogeneity (Redding and Venables, 2004; Anderson & Yotov, 2010). This approach is now widely applied for controlling unobserved bilateral and country-specific confounders. From another perspective, Santos Silva and Tenreyro (2006) showed that log-linear OLS estimates are inconsistent in the presence of heteroskedasticity and zeros and encouraged the implementation of Poisson Pseudo-maximum-likelihood (PPML) as a valid alternative. Following simulation and robustness checks (Silva and Tenreyro, 2011) confirmed PPML's favourable small-sample behaviour in datasets with many zeros. Complementing these findings, Helpman et al. (2008) emphasised that sample-selection and the extensive margin drive additional bias in naive specifications and proposed two-stage estimators that jointly model the probability of observing trade and the conditional trade volume, thereby explicitly addressing zero flows that reflect market entry decisions

rather than measurement error.

A third strand concerns comparative benchmarking and integrative synthesis. Stack (2009) and Head and Mayer (2014) systematically compare alternative specifications and estimators, showing how inference, for example the magnitude of integration dummies, is often sensitive to fixed-effects choices and estimator selection. Fally (2015) provides an important integrative contribution by reconciling structural gravity theory, PPML estimation and fixed-effects implementations under multilateral-resistance equilibrium constraints effectively connecting theory, estimator choice and identification in a unified framework. Proença et al. (2015) extend this practical toolkit by offering semi-mixed-effects models that blend fixed and random components, which can be especially useful in short panels or when facing complex heterogeneity that pure PPML and high-dimensional fixed effects struggle to capture.

Beyond dyadic estimators, a parallel methodological frontier incorporated network and spatial topologies into gravity reasoning. Kali and Reyes (2007) and Dueñas and Fagiolo (2011) adapted centrality and network measures to trade contexts, showing that a region's position in the global trade network conditions bilateral flows. Hübler (2016) further explored how network-theoretic formulations can be combined with gravity-type systems to represent interdependencies that aggregate local interactions into global patterns. Network extensions complement dyadic gravity models by capturing systemic spillovers and endogenous interdependence, but they also introduce identification and estimation challenges such as endogeneity of network position and higher computational burden that demand careful design and robustness checks.

Taken together, these studies point to practical trade-offs. For causal counterfactuals and policy evaluation where general-equilibrium feedback matter (e.g., infrastructure or tariff counterfactuals), structural gravity with multilateral-resistance consistency is preferable. For noisy, sparse interregional matrices, PPML with appropriate high-dimensional fixed effects provides a robust baseline. When zeros are plausibly driven by firm selection or market entry, two-stage selection models are recommended. Semi-mixed effects and network-augmented specifications provide flexible complements when panels are short or when systemic interdependence is central to the question. Finally, comparative benchmarking including simulation and counterfactual exercises, sensitivity analysis should be the routine. Method choice should be reported and carefully justified relative to the research question, data density, and the expected sources of bias.

3.2. Complementary approaches and regional trade estimation

A persistent challenge in the analysis of interregional trade is the estimation of bilateral flows when direct data are incomplete or unreliable. Glejser (1975) and Glejser et al. (1976) were among the first to highlight this problem and to propose early approximation methods for interregional transactions. In response, researchers developed a wide range of techniques that adapt the structural-gravity framework to data-scarce environments, often by combining it with complementary approaches such as spatial-interaction models, input-output (I-O) methods and network-based algorithms. Two broad strands of the literature can be distinguished.

The first strand relies on input-output methods, which treat the economy as an accounting system, connecting and tracing interdependencies across industries and regions as in a system of linear equations (Leontief, 1936). Leontief's I-O framework provided the foundational accounting structure subsequently adapted to regional contexts (Isard, 1954). Because survey-based regional I-O tables are costly, non-survey regionalisation techniques, most notably location quotients (LQs) and their refinements, were developed to approximate regional coefficients. The Flegg Location Quotient (FLQ) introduced a regional-size adjustment that mitigates the tendency of simple LQs to overstate self-sufficiency in small regions (Flegg et al., 1995; Flegg and

Webber, 1997).

While I-O methods ensure internal coherence within each regional system, they do not automatically guarantee consistency across regions or with national totals. The development of the multiregional I-O (MRIO) framework addressed this limitation by enforcing interregional balance and national consistency. Building on cross-entropy frameworks (e.g., Harrigan and Buchanan, 1984; Golan et al., 1994), Canning and Wang (2004), introduced a mathematical algorithm that reconciles preliminary estimates of interregional flows with observed aggregates, thereby producing internally consistent MRIO tables even when initial data are incomplete or noisy. Subsequent applications and refinements such as Llano's (2004) framework for Spain, its sectoral and transport extensions (Llano et al., 2010), and integrative toolkits like Miller and Blair (2009) expanded the method's empirical reach. Sargento et al. (2012) further demonstrated that MRIO accuracy improves when accounting procedures are complemented by behavioural or spatial constraints, bridging the gap between purely accounting-based and theory-consistent reconstructions.

The second methodological strand resolve around constrained gravity models, which estimate missing bilateral flows while ensuring consistency with observed regional aggregates. Originating in transportation planning (Wilson, 1971; Herijanto et al., 2005), these models retain the behavioural logic of the gravity framework linking trade intensity to economic mass and distance, while introducing balancing factors that align predicted flows with known origin and destination totals. Depending on the degree of constraint, the literature distinguishes between, unconstrained, singly constrained models, and doubly constrained models.

Unconstrained models rely on relatively simple computation methods and are used when data scarcity makes difficult to map the underline flows generation process. However, they often produce inaccurate estimates which do not truly represent the effective exchange between partners. Single constrained gravity models overcome this issue by introducing a balancing factor that ensure consistency with either total outflows or total inflows. This adjustment provides more realistic estimates, particularly when one side of the trade is well measured, however the unconstrained side generally does not match observed totals leading to systematic imbalances. In other words, while origin-constrained models ensure that total outflows from each region are satisfied, they do not guarantee that the corresponding inflows match, and vice versa. To overcome this limitation, doubly constrained gravity models introduce balancing factors for both origins and destinations, ensuring that row and column sums are simultaneously satisfied.

To achieve exact correspondence between estimated and observed totals, constrained gravity models are typically combined with iterative proportional fitting procedures such as the RAS algorithm or cross-entropy balancing. The algorithms adjust the initial gravity-generated matrix through successive proportional scaling of rows and columns until aggregate flows converge to target values. This procedure guarantees numerical consistency but introduces a well-known dependence on the initial distribution of flows: different priors or cost-function calibrations can yield alternative balanced matrices that fit the same constraints (e.g., Sargento et al., 2003, 2012). In fact, there is a continuum of potential matrices that would satisfy the constraints.

Recognising these trade-offs, a growing body of research has developed hybrid gravity-RAS approaches that merge the behavioural realism of gravity models with the accounting discipline of MRIO balancing. Ferreira (2008) applied this method to recover interregional trade flows within the Iberian Peninsula, demonstrating its feasibility in data-scarce environments. Subsequent contributions by Fournier Gabela (2020), Distefano et al. (2019) and Patandianan and Shibusawa (2020) validated gravity-RAS algorithms through benchmarking against observed or survey-based data, highlighting the role of calibration and prior accuracy in improving reconstruction quality. Cai (2023) further advanced this line of inquiry by showing that the precision of gravity-RAS estimates depends strongly on the specification of the cost function and the

quality of aggregate trade data used as constraints.

Taken together, these studies mark a transition from purely behavioural or accounting-based approaches to integrated, theory-consistent estimation frameworks. Constrained gravity and hybrid models strike a balance between the interpretability of structural gravity and the completeness of I-O accounting, offering a flexible yet rigorous tool for reconstructing interregional trade matrices. Their main comparative advantage lies in their ability to preserve both behavioural plausibility and numerical consistency, though at the cost of increased sensitivity to priors and calibration choices, an issue that remains central to ongoing methodological development.

3.3. Regional economic integration studies

Regional integration studies examine the effects of trade agreements, policy integration, and cooperation on bilateral trade, regional GDP and welfare. Empirically, this literature relies principally on structural gravity estimations, counterfactual simulations, panel and event-study designs to quantify the trade-creation and welfare effects of RTAs, accession and monetary unions (e.g., [Stack and Bliss, 2020](#); [Lyzun et al., 2024](#) [Nach and Nwadi, 2024](#)).

A consolidated body of research evaluates the trade and welfare consequences of EU accession, monetary integration and associated policy packages, using modern structural-gravity tools and counterfactual exercises. Studies combining long-run panels with counterfactual simulations typically conclude that deep and enforceable integration has raised bilateral trade and delivered measurable welfare gains, though the size and timing of those gains differ across members and over time. [Mayer, Vicard and Zignago \(2019\)](#) performed counterfactual structural-gravity and welfare simulations showing heterogeneous, often large welfare gains from EU integration. Similar results were obtained by [Camarero et al. \(2013\)](#) which used panel cointegration tests to assess the effects of the euro, finding positive but smaller effects compared to previous studies (e.g., [Bun and Klassen, 2007](#); [Gil-pareja et al., 2005](#)). [Glick \(2017\)](#) confirmed both results, highlighting the positive but heterogeneous effects of the EU and EMU, with substantial difference in favour of the EU: 70 % against 40 % increase. The study of [Glick, together with Maquez-Ramos \(2016\)](#), confirm both the direction and heterogeneity of these impacts, linking variation to institutional quality and policy design.

Methodological critiques stressed how cited average effects can mask important heterogeneity and are sensitive to specification choices. [Stack and Pentecost \(2011\)](#) demonstrated that richer fixed-effects structures and alternative estimators materially attenuate the estimated “EU effect”. Subsequent work that allows for time-varying, dyadic heterogeneity, and that distinguishes EU accession from EMU membership, finds large but non-uniform impacts across countries and sectors. [Stack and Bliss \(2020\)](#) extended the analysis accounting for omitted variable and simultaneity bias, finding positive yet heterogeneous and diminishing effects over time. The collective insight is clear: deep integration promotes trade, but empirical magnitudes depend heavily on specification, estimator choice, and data structure. Consequently, reliable policy inferences require both careful econometric practice and attention to the institutional and spatial conditions that influence integration’s effects.

Evidence from accession and regional-cluster studies refines this picture. These studies typically exploit event-study and panel-based designs to evaluate the localised effects of membership and regional agreements.

Research on the Western Balkans shows that agreements such as CEFTA 2006 generated measurable intra-regional trade creation. On the contrary, Stabilisation and Association Agreements (SAAs) often delivered limited gains especially in areas where competitiveness, institutional capacity, or political instability constrained the adjustment. Complementary analyses highlighted that these frameworks frequently advanced legal and institutional reform more than direct integration and trade expansion. [Dragutinović-Mitrović and Bjelić \(2015\)](#) emphasized

the role of EU accession and the coexistence of different trade regimes as key drivers of bilateral trade, noting that CEFTA 2006 significantly shaped intra-regional trade flows in the Western Balkans. Narrowing the focus, [Jošić and Bašić \(2021\)](#) analysed Croatia’s experience between 2000 and 2016, estimating gravity models with Random Effects (RE), PPML, and Tobit specifications. Their findings consistently point to a positive trade-creation effect from CEFTA membership, while accession to the EU generated significant trade diversion, underscoring the asymmetric impact of sequential integration stages on regional versus extra-regional trade.

Complementary evidence is provided by [Leka et al. \(2022\)](#), who highlighted the role of institutional and political factors in mediating the effectiveness of trade agreements, arguing that in the Western Balkans free trade arrangements have often had a stronger impact on legal and institutional reform than on direct trade expansion. Adding further nuance, [Leka and Jusufi \(2024\)](#) found that the SAAs did not lead to sustained export growth from the region, as products originating in the Western Balkans remain largely uncompetitive in EU markets; instead, EU exports to the region expanded more strongly, raising concerns about asymmetric benefits.

A parallel literature on regional clusters and subnational integration, notably the Baltic Sea Region (e.g., [Schlitte and Paas, 2008](#)), shows that enlargement and cluster membership deepen intra-regional linkages, but gains remain spatially uneven and sector specific. Core, export-oriented areas capture most benefits, while peripheral or less diversified regions lag behind.

[Paas and Tafenau \(2005\)](#), explored EU enlargement to the Baltic Sea Region (BSR), revealing that regional clusters have emerged as powerful integration forces. Their results, echoing [Leka et al. \(2022\)](#) for the Western Balkans, emphasize the enduring role of historical ties, economic scale, and regional cooperation in shaping post-enlargement trade patterns. More recently, [Szejgic-Kolenda and Duma \(2020\)](#) analysed BSR trade linkages from 2011 to 2019, following enlargement and the implementation of the EU Strategy for the BSR. They documented a 46.3 % increase in trade volume, more pronounced in goods than in services, and confirmed the deepening of intra-regional ties, although uneven across space and sectors. Subnational analyses reinforce that classical gravity determinants such as distance and economic scale continue to shape flows, particularly between Polish regions and Nordic partners. These results mirror the Western-Balkan evidence: institutional readiness and historical ties mediate the capacity to exploit integration.

Methodologically, these studies highlight the value of exploiting temporal variation around accession or agreement implementation (event-study) and of employing subnational data to uncover distributional impacts hidden in country-level averages. The policy implication is clear: legal and market-access reforms are necessary but not sufficient; they must be paired with competitiveness upgrades (infrastructure, skills, firm capabilities) and political stabilization if integration is to deliver sustained trade gains. For researchers, stronger causal designs difference-in-differences with credible controls, synthetic controls, or instrumental variables and a wider use of region-level microdata would sharpen inference on who gains, who loses, and why.

Taken together, the literature converges on a cautiously optimistic verdict. Regional integration tends to be positively correlated with raising bilateral trade and can generate welfare gains, but this aggregate result conceals important variation in timing, magnitude and distribution. EU-level counterfactual and long-run panel studies (e.g. [Mayer et al., 2019](#); [Camarero et al., 2013](#); [Glick, 2017](#)) provide strong evidence that comprehensive, enforceable integration packages and monetary unions expand trade and welfare, particularly for countries well-prepared to participate in integrated markets. By contrast, case studies of accession and cooperation agreements (CEFTA, SAAs) reveal a more conditional story: CEFTA often produces measurable intra-regional creation ([Jošić and Bašić, 2021](#); [Dragutinović-Mitrović & Bjelić, 2015](#)), yet SAAs and accession paths in less competitive or

politically fragile settings frequently translate into limited export gains or asymmetries in trade flows (Leka et al., 2022; Leka and Jusufi, 2024). Regional cluster work (Baltic Sea Region and subnational studies) shows that clusters and proximity can amplify integration benefits locally (Paas and Tafenau, 2005; Szejgiec-Kolenda and Duma, 2020), but the gains are spatially uneven and sector-specific core areas and GVC-ready sectors capture most of the upside while peripheries may lag or even suffer relative losses.

Why do findings differ? Much of the divergence is methodological and contextual. Empirical magnitudes are highly sensitive to estimation choices (PPML vs log OLS, treatment of zeros), to fixed-effects strategies and multilateral-resistance controls (Stack and Pentecost, 2011), and to whether studies examine gross vs value-added flows. Endogeneity and selection into agreements (who joins, when and why) bias naïve estimates unless addressed with event-study designs, synthetic controls, IVs or carefully specified DiD. Data limitations also matter: MRIO and gravity-RAS hybrids can recover missing interregional flows and add sectoral richness, but their reconstructions depend on priors and calibration (Distefano et al., 2019; Fournier-Gabela, 2020; Cai, 2023). In short, the observed heterogeneity is the product of real institutional/contextual differences reinforced by methodological choices — both must be accounted for before drawing normative policy conclusions.

3.4. Sector-specific applications

A growing strand of the gravity literature has focused on unpacking the sectoral and structural heterogeneity of trade responses, extending the model beyond aggregate flows to examine industry-specific patterns, production networks, and factor mobility. These applications consistently suggest that the elasticity of trade to distance, policy, and integration varies sharply across sectors, reflecting underlying differences in scale economies, technological intensity, and value-chain position.

Early contributions already pointed to this pattern, yet with different emphases. Marques and Metcalf (2005) and Martínez-Zarzoso and Márquez-Ramos (2007) demonstrated that technological capability and human capital amplify integration gains, leading high-skill, capital-intensive sectors to benefit differently from others. Complementing, Bensassi et al. (2015) identified infrastructure, as a key mediator of regional competitiveness, linking connectivity to productivity and trade efficiency. Together, these contributions laid the conceptual and empirical groundwork for sector specific gravity models that explicitly incorporate technology, infrastructure and industrial structure when mapping the geography of trade.

Infrastructure has emerged as another key comparative dimension. Structural-gravity analyses of EU regions (Shevtsova et al., 2025; Zani-novic et al., 2024; Barbero et al., 2021; Oesingmann, 2022) collectively show that infrastructure type and distribution crucially condition trade capacity. Road improvements raise regional exports and GDP but disproportionately benefit core regions, while ICT and border-efficiency investments enhance supply-chain trade and mitigate peripherality. Air-cargo evidence suggests that supranational agreements (Schengen, the Euro) influence logistics networks differently from goods trade, underscoring the sector-specific sensitivity of transport and digital infrastructures. Taken together, these results portray infrastructure as both an enabler of trade and an amplifier of spatial inequality.

Agricultural and resource-based sectors display yet another configuration. Studies of the EU (Sarker and Jayasinghe, 2007; Balogh and Leitão, 2019) find that integration fostered strong intra-EU agri-food trade but diverted flows from non-members, while research on developing regions (Houeninvo and Sèdédji, 2019) shows that agricultural exports within WAEMU depend jointly on GDP, FDI and logistical investment. Comparing these results highlights a structural asymmetry: in high-income settings, integration consolidates existing trade networks, whereas in low-income regions, complementary investments and institutional capacity remain binding constraints for realising integration's potential.

While this review focuses on interregional trade, it is worth noting that the gravity framework has also been applied to other forms of cross-border interaction, such as labour mobility and FDI, reinforcing its versatility as a spatial interaction model (Goel, 2015; Chenaf-Nicet and Rougier, 2016; Persyn and Torfs, 2016; Riache et al., 2020).

Across sectors and factors, three comparative lessons emerge. First, the drivers of trade are sector- and context-specific: technology, infrastructure, and institutional depth matter more than policy per se. Second, integration yields uneven spatial and sectoral returns: manufacturing and core regions capture disproportionate gains, while agriculture and peripheral areas lag without complementary investment. Third, methodological diversification, combining structural gravity with network, MRIO, or event-study designs, has been essential in uncovering these heterogeneous patterns, turning gravity analysis into a genuinely multi-sector and multi-factor framework for studying integration.

4. Discussion

Understanding interregional trade requires analytical tools that move beyond descriptive accounting to capture multi-layered interactions among regions, the architecture of rules that govern market access, and the infrastructural and behavioural conditions that shape economic exchange. The gravity model remains the central diagnostic device in this literature, but its diagnostic power depends on two things: methodological choices such as estimator, fixed effects, treatment of multilateral resistance, and reconstruction procedures when data are missing; and sectoral/contextual specification, gross vs value-added measurement, product/sector heterogeneity, and regional institutional features. This discussion synthesises methodological advances, revisits the border effect as a graded and endogenous phenomenon, compares sectoral evidence, and draws implications for policy and future research. Wherever appropriate, we link the interpretation to the empirical results presented in the previous section. In doing so, the paper critically engages with both the strengths and limitations of current applications, offering a platform for deeper inquiry into how trade models can better reflect the evolving European economic landscape.

4.1. Methodological advances in gravity-based inference

Recent developments have substantially refined gravity-based approaches to interregional trade estimation. Key contributions include the adoption of robust count-model estimators such as PPML, richer fixed-effects structures that control for multilateral resistance and dyadic heterogeneity, and semi-mixed effect estimators for short panels. Furthermore, spatial and network extensions now allow gravity models to account for topology and indirect linkages, as shown in the works of (Anderson, 2011; Anderson and van Wincoop (2003), Shevtsova et al., 2025, Proença et al. (2015), and Stack (2009). A key consensus has emerged: model specification strongly conditions inference. PPML estimators systematically yield smaller distance elasticities and more stable coefficients than OLS, confirming the sensitivity of border estimates to econometric choices. Yet, divergence remains over how to model unobserved heterogeneity, particularly when panel depth is limited. While some authors (Shevtsova et al., 2025) propose semi-mixed models to address short panels, others (Proença et al., 2015) emphasize spatial lag structures to capture interregional dependence. Indeed, methodological progress has improved the credibility of interregional gravity estimates, but comparability across studies remains constrained by inconsistent treatment of heterogeneity. Future work should prioritize harmonized estimation protocols and replication standards, as advocated by Head and Mayer (2013), (2014).

4.2. Data reconstruction and hybrid estimation

Equally important are advances in data reconstruction techniques,

data incompleteness continues to challenge interregional trade modelling, particularly where customs or survey data are missing. Methods such as multi-regional input–output (MRIO) models, gravity–RAS hybrids, cross-entropy approaches, and Bayesian priors enable the recovery of bilateral flows where survey or customs microdata are incomplete (Ferreira, 2008; Llano, 2004; Sargento and Nogueira Ramos, 2003; Distefano et al., 2019; Cai, 2023). These techniques show clear complementarities. Gravity provides a theoretically consistent prior; I–O and RAS ensure accounting coherence.

Yet, the literature also reveals fragility: reconstructed matrices depend heavily on the choice of seed matrix, cost function, and convergence tolerance. Small adjustments in priors can produce materially different bilateral flows even under identical margins. This raises concerns about identification and reproducibility, underscoring the need for transparent sensitivity testing and benchmarking against auxiliary sources (freight data, transport statistics, partial surveys). Where studies diverge is in how they validate reconstruction quality, some emphasize internal consistency, others external plausibility.

A comparative synthesis shows that Bayesian and cross-entropy priors outperform pure RAS in recovering realistic trade intensities, particularly in data-scarce regions. In conclusion, hybrid estimation strategies have emerged as particularly versatile. However, these procedures are sensitive to prior assumptions and calibration parameters, including the seed matrix, cost function, and convergence criteria. Identification sensitivity remains a critical issue: while IPF converges to a unique solution conditional on consistent margins, the outcome depends on the researcher's initial choices. Therefore, these methods require explicit calibration standards. The field would benefit from a unified validation framework such as reporting priors, elasticities, and sensitivity intervals to ensure that reconstructed values are analytically and policy credible.

4.3. The border effect as a dynamic and endogenous construct

A major theoretical shift in recent years has been the move from viewing borders as static, binary barriers to treating them as multi-dimensional, endogenous constructs. Borders are now understood as products of legal frameworks, political narratives, and infrastructural connectivity rather than mere geographical discontinuities (Niebuhr and Stiller, 2006; Persyn and Torfs, 2016; Lipps et al., 2021). Comparative evidence shows declining but uneven border effects across Europe. Membership in the Single Market and Eurozone consistently reduces trade frictions, yet the magnitude of reduction varies with institutional capacity and policy alignment (e.g., Novak et al., 2022; Müller, 2016). Sectoral heterogeneity further complicates this picture: studies by Guedidi et al. (2024) and Wang et al. (2021) confirm that final goods exhibit faster integration than intermediate inputs, which remain constrained by regulatory fragmentation within Global Value Chains. Behavioural and political dimensions also matter. Studies (e.g., Lipps et al., 2021; Leka et al., 2022; Stiller, 2006) show that public sentiment toward borders, shaped by securitization and identity narratives, affects preferences for cross-border cooperation. Furthermore, some research also shows that in borders with higher integration levels, the negative impacts of borders may also be higher, because of the more abundant impacted interactions. This explains why in Europe the highest estimated border effect is amongst the border regions of EU-6 (EC 2017a; Camagni et al., 2017). Therefore, the border effect is not uniform but context-specific, shaped by governance design, sectoral integration, and societal attitudes (Capello et al., 2017). Analytical models should thus move from binary dummies toward graded measures of border permeability, integrating institutional and behavioural indicators.

4.4. Reconceptualising the border effect

The “border effect” remains a central and puzzling feature in the gravity literature. Despite decades of European integration, empirical

estimates continue to reveal that national borders exert a disproportionate dampening effect on trade flows even within the EU. Traditionally, borders were treated as binary frictions, but recent research increasingly conceives them as multi-dimensional, partly endogenous constructs shaped by legal, institutional, infrastructural, and behavioural forces (Stiller, 2006; Lipps et al., 2021; Camagni et al., 2019; Dellmuth, 2023; Persyn and Torfs, 2016). This reconceptualization helps explain the heterogeneity of border penalties across regions, sectors, and time. Institutional and administrative frictions, not geography alone, account for much of the residual trade resistance observed in gravity estimates. Moreover, reductions in the border effect tend to be sector-specific: final goods exhibit greater integration gains than intermediate inputs, consistent with findings by Guedidi et al. (2024) and Wang et al. (2021), who show that intermediate inputs remain particularly sensitive to procedural and regulatory barriers in global value chains (GVCs). A series of studies (e.g., Novak et al., 2022; Müller, 2016) confirm that EU Single Market and Eurozone membership substantially reduce trade frictions, though effects depend on the structural characteristics of participating economies. Persistent barriers often stem from regulatory divergence, linguistic and cultural differences, or national taxation regimes. Persyn and Torfs (2016) highlight the influence of commuting and labour mobility on cross-border trade, suggesting that labour market integration should be explicitly modelled. Lipps et al. (2021) add a behavioural dimension, showing that public sentiment and political framing of borders influence policy preferences and, indirectly, the permeability of borders themselves. Securitization narratives emphasizing cooperative border governance tend to mitigate polarization more effectively than those centred on physical infrastructure. At the institutional level, Stiller demonstrates that trade governance itself reconfigures territorial boundaries: through FTAs and EU regulatory mechanisms, borders are effectively “redrawn,” “shifted,” or “blurred.” This flexible territoriality complicates the binary conception of borders in gravity modelling, calling for more nuanced measures of border permeability. The case of the UK's post-Brexit arrangements, especially the hybrid status of Northern Ireland, illustrates this complexity vividly.

4.5. Sectoral and structural dimensions

Sector-specific applications of the gravity model further challenge traditional assumptions. Guedidi et al. (2024) show that cross-border trade facilitation measures such as improved logistics or customs efficiency, have markedly different effects across sectors. Final goods respond more strongly to integration initiatives, while intermediate goods remain constrained by regulatory and procedural rigidity. Franco-Bedoya and Frohm (2022) find that FTAs can increase trade in final goods by up to 52 % over a decade, yet intermediate trade remains more resistant to policy harmonization.

Complementary studies by Salas-Olmedo et al. (2015) and Camagni et al. (2018) underscore how infrastructural and administrative disparities mediate the border effect, particularly in peripheral regions. Despite the EU's structural and cohesion policies, many border regions remain hampered by lower accessibility and higher multilateral resistance, indicating that legal harmonization alone is insufficient without parallel investments in transport and institutional coordination. These findings illustrate the relevance of EU's support to cross-border cooperation being enlarged with tools other than funding, to facilitate solving border obstacles (Ferreira et al., 2019). The Iberian Peninsula offers an illustrative example. González et al. (2017) document a long-term process of “de-bordering” between Spain and Portugal, driven by increasing economic and political cooperation. Yet, this trajectory has not been linear: the post-2008 crisis and more recent geopolitical shocks have triggered instances of “re-bordering,” revealing the fragility of integration under economic stress. Gallego and Llano (2015) provide quantitative evidence showing that while intra-national trade still dominates, there remains considerable untapped potential for deeper cross-border integration, particularly in peripheral regions.

4.6. Infrastructure, technology, and new frontiers of trade

Infrastructure remains a decisive factor in determining trade intensity. Studies by [Shevtsova et al. \(2025\)](#) and Hoffmann (2023) show that transport investments, especially in high-speed rail networks and logistics hubs, significantly enhance interregional connectivity. Ferrari et al. (2023) find that maritime connectivity is particularly crucial for high-value, time-sensitive goods, while [Wang et al. \(2022\)](#) demonstrate that high-speed rail strengthens urban-to-urban exchanges, can enhance the inter-regional flow of labour factors, promoting knowledge exchange and the formation of innovation. These findings underscore the need for multimodal logistics strategies integrating rail, road, air, and maritime transport to optimize regional trade networks.

Meanwhile, sectoral analyses of agriculture and digital trade reveal the evolving limits of the traditional gravity model. Hansen (European Parliament, 2024) highlight how CAP subsidies shape agricultural trade patterns by altering regional competitiveness and self-sufficiency, while López-Gonzalez (2017) shows that in digital trade, proximity increasingly gives way to regulatory and infrastructural factors such as cybersecurity, data governance, and digital infrastructure, rendering physical distance less relevant. As a result, gravity models must evolve to incorporate technological and policy variables that shape virtual flows of goods and services.

4.7. Policy relevance: addressing border related barriers

The persistence of border effects revealed in our analysis has clear implications for regional policy. EU Cohesion Policy and related funding instruments (such as Interreg) have long sought to foster cross-border integration, yet our findings suggest that physical and administrative frictions still play a significant role. Strengthening cross-border transport connectivity, harmonising regulations for cross-border commuters and firms, and supporting joint regional planning through EGTCs could help mitigate these effects. Similar priorities are echoed in recent evaluations ([European Commission, 2022](#); [Laguna, 2024](#)) and OECD reports ([OECD, 2024](#)), which stress the need to align local development strategies with functional cross-border dynamics.

The persistence of border effects across European regions highlights the ongoing relevance of policy frameworks that explicitly seek to enhance cross-border integration and reduce territorial discontinuities. The European Union's Cohesion Policy, and in particular its European Territorial Cooperation (ETC) strand (commonly known as Interreg) has been the main policy instrument addressing cross-border barriers for over three decades. Its aim to foster economic, social, and territorial cohesion across national borders directly targets the spatial frictions observed in our results. Yet, consistent with the findings of recent evaluations ([Medeiros, 2018](#); [Laguna, 2024](#); [ESPON, 2022](#)), the persistence of significant border effects in trade (other than labour mobility or knowledge transfer) suggests that structural and administrative obstacles remain deeply embedded in the institutional geography of border regions.

A key lesson emerging from both research and policy practice is that cross-border cooperation must evolve beyond project-based funding toward durable governance structures. Instruments such as the European Groupings of Territorial Cooperation (EGTCs) have been promoted to institutionalise joint planning and service provision across borders ([Camagni, 2008](#); [Camagni and Capello, 2013](#); [Camagni et al., 2017](#)). However, their uneven capacity and limited policy competences often constrain their effectiveness. Empirical evidence from [OECD \(2013a\), \(2013b\), \(2024\)](#) [OECD, 2013](#) and [ESPON \(2022\)](#) reports indicates that regions where EGTCs are coupled with strong national or regional policy support (such as in the Upper Rhine, the Tyrol–South Tyrol–Trentino Euroregion, or Øresund) exhibit more integrated labour markets and denser cross-border innovation linkages. Complementing formal interventions, locally embedded actors such as NGOs can strengthen community engagement, local trust across the border, and sustain

service provision where formal institutions are weak ([Potluka and Schubnell, 2023](#); [Potluka et al., 2025](#)). However, such contribution is often limited by funding instability, limited scale, and representativeness, so NGOs typically complement rather than replace formal cross-border governance. This reinforces the view that the border effect is not purely a matter of geography but of institutional coordination and policy capacity.

Another policy dimension concerns infrastructure and accessibility, long recognised as key determinants of spatial interaction ([Rodríguez-Pose, 2020](#)). EU-funded transport corridors, notably under the Connecting Europe Facility and the TEN-T framework, have sought to physically reconnect border territories. Yet studies show that soft barriers, such as regulatory mismatches, language divides, culture disparities, and labour-market fragmentation, often persist even where physical connectivity has improved ([Niebuhr and Stiller, 2006](#); [Edzes et al., 2022](#); [Tsiopa et al., 2024](#)). Particularly, recent work on the Minho River area ([Jardón et al., 2024](#)) shows how shared cultural and commercial traits can shape cross border interactions, demonstrating that human capital, in particular skill gaps and recognition barriers can outweigh the benefits from agglomeration and proximity. This aligns with our findings, suggesting that policy interventions need to combine *hard* (infrastructure) and *soft* (institutional and socio-cultural) integration measures to generate durable reductions in border frictions.

Region-based policy interventions offer instructive contrasts. In the Øresund Region (Denmark–Sweden), for instance, sustained investment in cross-border infrastructure has been paired with coordinated labour market initiatives and university collaborations, substantially reducing perceived distance despite persistent regulatory and fiscal barriers ([Nauwelaers et al., 2013](#); [Illing, 2025](#)). Along the Upper Rhine, long-standing cooperation under the RegioTriRhena and subsequent EGTC structures has fostered institutionalized networks in transport, showing that policy continuity can gradually erode the functional impact of borders ([Perkmann, 2003](#); [ESPON, 2022](#)). Similar integrative approaches are emerging in Central Europe through the Danube Transnational Programme and in the Baltic Sea Region, where joint innovation strategies and cross-border smart specialisation initiatives are aligning regional innovation ecosystems ([European Commission, 2022](#); [Foray et al., 2021](#); [Hegyi et al., 2021](#); [Kim et al., 2024](#)).

In contrast, several Southern and Eastern European border areas still display weak policy integration and limited cross-border institutional density. The Iberian border between Spain and Portugal, for example, remains characterised by asymmetric economic structures and fragmented governance despite substantial ETC funding ([Medeiros, 2018](#)). Similarly, Central-Eastern borders (e.g., Poland-Ukraine, Hungary-Romania) face discontinuities in administrative and legal frameworks that hinder the formation of functional regional systems ([Nagy, 2006](#); [Malkowski et al., 2024](#); [Wolodin, 2024](#)). These cases highlight the uneven territorial reach of European policy instruments and suggest that sustained reductions in border effects depend not only on financial support but on coherent, multilevel governance architectures capable of aligning incentives across jurisdictions.

At a broader scale, the place-based approach embedded in the EU's regional policy ([Barca, 2009](#); [Camagni, 2013](#)) calls for territorial strategies grounded in local assets and governance networks. This perspective implies that the border effect should be tackled through tailored local policies, jointly designed by neighbouring regions to exploit complementarities rather than compete for resources. This argument is particularly relevant for policies that revolve around a common identification but rely on local implementation, where proximity to other regions presents both coordination opportunities and costs. Recent comparative evidence shows that cross-border regions often struggle to align climate-change strategies and investment frameworks across national jurisdictions, with divergent administrative systems and planning cycles limiting the effectiveness of joint adaptation and mitigation efforts (e.g., [Cappellano, Kurowska-Pysz and Jakubowski, 2025](#); [Talebian et al., 2025](#)). Similar challenges arise for

innovation and industrial development, where joint governance can also amplify cross-border complementarities. Cross-border smart specialisation strategies (Foray et al., 2021; Hegyi et al., 2021; Kim et al., 2024) offer a promising avenue, encouraging regions to co-invest in innovation ecosystems that transcend administrative boundaries.

The evidence points to the need for multi-level and cross-sectoral coordination in addressing border effects. Policies should simultaneously enhance both tangible and intangible connectivity. The persistence of measurable border effects despite decades of territorial cooperation underscores the importance of refining the policy mix, from isolated interventions to integrated, long-term regional strategies consistent with the EU's goal of territorial cohesion.

5. Conclusion

This paper has critically examined the evolving landscape of inter-regional trade estimation as a lens through which to understand the mechanisms and limitations of economic integration, with a particular emphasis on regional dynamics and the persistent border effect. Having reviewed recent advancements in gravity modelling and the empirical evidence from regional integration experiences, especially within the European Union, the study reveals both the methodological sophistication and conceptual ambiguity that continue to shape this field.

One of the core insights to emerge from the literature is that regional economic integration remains a complex and uneven process, shaped as much by infrastructural and institutional realities as by formal agreements. Despite decades of policy efforts aimed at fostering deeper cohesion such as the EU's macro-regional strategies and investment and funding frameworks, the border effect continues to exert a significant, and often underestimated, influence on trade flows, even in advanced integration zones. This underscores a critical paradox: while economic borders may be legally dismantled, their functional and symbolic weight persists through relevant channels such as cultural, political, social, and administrative. Incompatible national legal frameworks are a major source of these persistent border obstacles and can even create reinforcing cycles: the more intense cross-border interactions become, the more those legal frameworks need to be compatible, thus unresolved discrepancies generate additional frictions that expose further obstacles and make additional incompatibilities easier to identify.

Methodologically, the gravity model remains the dominant analytical framework for trade estimation, but its continued relevance hinges on its adaptability. Innovations such as hybrid gravity-input-output models, the integration of complex network analysis, and the inclusion of behavioural and political dimensions (e.g., public perception of borders) have enriched its explanatory capacity. However, the model's limitations, especially in accounting for asymmetric relationships, informal trade, and sector-specific dynamics, demand further refinement. Notably, the traditional binary treatment of borders as either present or absent fails to capture the multidimensional and context-dependent nature of border permeability in the modern economic landscape.

The findings also highlight the need for disaggregated region-specific analysis. Integration does not produce uniform outcomes; it is mediated by regional infrastructure, institutional readiness, political will, and historical trajectories. As such, future research must avoid over-generalisation and instead adopt more granular approaches that account for the socio-spatial heterogeneity of integration effects. In this line it's particularly relevant the discussion on the delimitation of border regions according to the different functionalities of the territory. The use of geolocalised grid data, going beyond the limitations of data based on administrative regions has a high potential. In this line its illustrative the work of Kavalov et al. (2019) delineating border regions according to the driving time distance of each grid point to the closest border crossing point.

From a policy perspective, the literature reviewed suggests that legal (and data) harmonisation and trade facilitation measures, while

necessary, are insufficient. To realize the full potential of economic integration, investment must be directed toward reducing non-tariff and infrastructural barriers, improving data systems for interregional trade measurement, and fostering social and institutional trust across borders. The growing relevance of digital trade and environmental goods further implies that integration strategies must be forward-looking, aligning with emergent economic and technological realities.

Looking ahead, three broad trends stand out in the evolving study of interregional trade and border effects. First, methodological convergence is evident: hybrid frameworks combining gravity, input-output, and spatial econometric approaches are increasingly used to handle data limitations and multi-level interactions. Second, there is a growing shift toward high-resolution and behavioural perspectives, integrating geolocated data, firm-level evidence, and perceptions of borders to better capture how integration unfolds in practice. Third, machine learning and data-driven modelling are beginning to complement traditional econometric approaches, particularly in reconstructing missing trade matrices, detecting non-linear relationships, and improving predictive accuracy. Finally, future research is moving toward a more interdisciplinary understanding of borders, linking trade modelling with political economy, governance, and digital connectivity, to explain why integration remains uneven despite decades of policy effort. These trends suggest that the next generation of studies will increasingly rely on both methodological innovation and cross-domain collaboration to reassess the border effect in a rapidly transforming economic landscape.

This paper contributes to the scholarly and policy debate by offering a critical synthesis of how interregional trade estimation intersects with the broader goals of economic integration. It argues for a reconceptualization of borders not as static lines, but as fluid, socially constructed interfaces shaped by both formal policies and informal practices. To better understand and guide integration processes in an era of geopolitical uncertainty and technological transformation, future research must integrate economic modelling with political, spatial, and sociological insights, ensuring a more holistic and actionable understanding of how regions connect, and where they continue to diverge.

CRedit authorship contribution statement

Daniele Bregoli: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Giacomo Arena:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ricardo Ferreira:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marco Ciro Liscio:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Paolo Sospiro:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

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

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References

- Anderson, J.E., 1979. A theoretical foundation for the gravity equation. *Am. Econ. Rev.* 69 (1), 106–116.
- Anderson, J.E., Yotov, Y.V., 2010. The changing incidence of geography. *Am. Econ. Rev.* 100 (5), 2157–2186.
- Anderson, James E., 2011. The gravity model. *Annu. Rev. Econ. Annu. Rev.* 3 (1), 133–160, 09.
- Anderson, James, E., van Wincoop, Eric, 2003. Gravity with gravitas: a solution to the border puzzle. *Am. Econ. Rev.* 93 (1), 170–192.
- Arkolakis, Costas, Demidova, Svetlana, Klenow, Peter J., Rodriguez-Clare, Andres, 2008. Endogenous variety and the gains from trade. *Am. Econ. Rev.* 98 (2), 444–450.
- Balassa, B., 1961. Towards a theory of economic integration. *Kyklos* 14, 1–17.
- Balogh, Jeremiás Máté, Leitão, Nuno Carlos, 2019. A gravity approach of agricultural trade: the nexus of the eu and african, caribbean and pacific countries. *Agric. Econ.* 65, 11.
- Barbero, Javier, Mandras, Giovanni, Rodríguez-Crespo, Ernesto, Rodríguez-Pose, Andrés, 2021. Quality of government and regional trade: evidence from European union regions. *Reg. Stud.* 55 (7).
- Barca, F. (2009). *An Agenda for a Reformed Cohesion Policy: A place-based approach to meeting European Union challenges and expectations*. Independent report for the European Commissioner for Regional Policy, European Commission.
- Bekbolotova, S., Djanibekov, N., Herzfeld, T., 2025. How does regional economic integration impact trade in small economies? Evidence from Armenia and Kyrgyzstan's EAEU accession. *Eurasia Geogr. Econ.* 1–29.
- Bensassi, S., Márquez-Ramos, L., Martínez-Zarzoso, I., Suárez-Burguet, C., 2015. Relationship between logistics infrastructure and trade: Evidence from Spanish regional exports. *Transp. res. part A: policy pract.* 72, 47–61.
- Bergstrand, J.H., 1985. The gravity equation in international trade: some microeconomic foundations and empirical evidence. *Rev. Econ. Stat.* 67 (3), 474–481.
- Bergstrand, J.H., 1989. The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade. *Rev. Econ. Stat.* 71 (1), 143–153.
- Beyer, R.C., Li, C., Weber, M.S., 2025. Economic Benefits from Deep Integration: 20 years after the 2004 EU Enlargement. *Int. Monet. Fund.*
- Brunet-Jailly, E., 2011. Borders, borderlands and theory: an introduction. *Geopolitics* 16 (1), 1–6.
- Bun, M.J.G., Klaassen, F.J.G.M., 2007. The euro effect on trade is not as large as commonly thought. *Oxf. Bull. Econ. Stat.* 69 (4), 473–496.
- Thiess Büttner, and Johannes Rincke. (2004). *Labor Market Effects of Economic Integration - The Impact of Re-Unification in German Border Regions*. CESifo Working Paper Series 1179, CESifo.
- Cai, M., 2023. A calibrated gravity model of interregional trade. *Spat. Econ. Anal.* 18 (1).
- Camagni, R., 2008. Regional competitiveness: towards a concept of territorial capital. *Model. Reg. Scenar. Enlarg. Eur.*
- Camagni, R., Capello, R., 2013. Regional competitiveness and territorial capital: a conceptual approach and empirical evidence from the EU. *Reg. Stud.* 47 (9), 1383–1402.
- Camagni, R., Capello, R., Caragliu, A., and Toppeta, A. (2017). *Quantification of the effects of legal and administrative border obstacles in land border regions* - ISBN.
- Camagni, R., Capello, R., Caragliu, A., 2019. Measuring the impact of legal and administrative international barriers on regional growth. *Reg. Sci. Policy Pract.* 11 (2), 345–367.
- Camarero, M., Gómez, E., Tamarit, C., 2013. Emu and trade revisited: Long-run evidence using gravity equations. *World Econ.* 36 (9), 1146–1164.
- Camera, G., Hohl, L., Weder, R., 2023. Inequality as a barrier to economic integration? An experiment. *Exp. Econ.* 26, 383–411.
- Canning, P., Wang, Z., 2005. A flexible mathematical programming model to estimate interregional input–output accounts. *J. reg. sci.* 45 (3), 539–563.
- Capello, R., Caragliu, A., Fratesi, U., 2017. Measuring border effects in European cross-border regions. *Reg. Stud.* 52 (7), 986–996.
- Capoani, L., 2023. Review of the gravity model: origins and critical analysis of its theoretical development. *SN Bus. Econ.* 3, 95.
- Cappellano, F., Kurowska-Pysz, J., Jakubowski, A., 2025. A comparative policy approach to climate change in cross-border regions. *Reg. Sci. Policy Pract.* 17.
- Carter, D.B., Poast, P., 2020. Barriers to trade: how border walls affect trade relations. *Int. Organ.* 74 (1), 165–185.
- Chakraborty, I., Hai, R., Holter, H.A., Stepanchuk, S., 2017. The real effects of financial (Dis)integration: a multi-country equilibrium analysis of Europe. *J. Monet. Econ.* 85, 28–45.
- Chaney, Thomas, 2008. Distorted Gravity: the intensive and Extensive Margins of International Trade. *Am. Econ. Rev.* 98 (4), 1707–1721.
- Chen, W.C., 2024. The impacts of policy restrictions on trade in services". *Appl. Econ.* 57 (39), 6166–6181.
- Chenaf-Nicet, Dalila, Rougier, Eric, 2016. The effect of macroeconomic instability on fdi flows: a gravity estimation of the impact of regional integration in the case of euro-mediterranean agreements. *Int. Econ.* 145.
- Colantone, I., Crinó, R., Ogliaresi, L., 2015. The hidden cost of globalization: import competition and mental distress. *Health Econ. eJournal.*
- Distefano, T., Tuninetti, M., Laio, F., Ridolfi, L., 2019. Tools for reconstructing the bilateral trade network: a critical assessment. *Econ. Syst. Res.* 32 (3), 378–394.
- Dragutinović-Mitrović, R., Bjelić, P., 2015. Trade regimes and bilateral trade in the EU enlargement process: Focus on the Western Balkans. *Acta Oeconomica* 65 (2), 249–270.
- Eaton, J., Kortum, S., 2002. Technology, geography, and trade. *Econometrica* 70 (5), 1741–1779.
- Duenas, Marco and Fagiolo, Giorgio. (2011). *Modeling the International-Trade Network: A Gravity Approach*, Papers 1112.2867, arXiv.org.
- Ecohard, P., Fontagné, L., Gaulier, G., and Zignago, S. (2006). "Intra-Industry Trade and Economic Integration". Hiratsuka, D. (eds) *East Asia's De Facto Economic Integration*.
- Edzes, Arjen, Dijk, Jouke, Broersma, Lourens, 2022. Does cross-border commuting between EU-countries reduce inequality? *Appl. Geogr.* 139.
- ESPON (2022). *Cross-border Public Services 2.0*. ESPON Report.
- European Commission. 2017. *Communication from the Commission to the Council and the European Parliament - Boosting growth and cohesion in EU border regions* - COM(2017) 534.
- European Commission. 2017a. "COMMISSION STAFF WORKING DOCUMENT Accompanying the document COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on Boosting Growth and Cohesion in EU Border Regions" - SWD(2017)307.
- European Commission 2022: Directorate-General for Regional and Urban Policy, Peyrony, J., Devillard, T., Rubió, J. and Viaggi, R., *Analysis of the impact of border-related measures taken by Member States in the fight against COVID-19*, Publications Office of the European Union, 2022.
- Egan, M., Guimarães, M.H., 2017. The single market: Trade barriers and trade remedies. *JCMS: J. Common Mark. Stud.* 55 (2), 294–311.
- Evenett, Simon J., Keller, Wolfgang, 2002. On theories explaining the success of the gravity equation. *J. Political Econ.* v110 (2, Apr), 281–316.
- Fally, Thibault, 2015. Structural gravity and fixed effects. *J. Int. Econ.* 97 (1), 76–85.
- Ferreira, R., 2008. Comércio Inter-regional Ibérico. *Assoc. çao De. Desenvol. Reg. do Inst. Polit. écnico De. Portal.*
- Ferreira, Ricardo, Verschelde, Nathalie, Cenacchi, Valeria, 2019. Debating European Commission's support to Cross-Border Cooperation: Time to move beyond funding. *Reg. Mag.*
- Fidrmuc, J., Hainz, C., 2013. The effect of banking regulation on cross-border lending. *J. Bank. Financ.* 37, 1310–1322.
- Flegg, A.T., Webber, C.D., 1997. On the appropriate use of location quotients in generating regional input-output tables: reply. *Reg. Stud. Taylor Fr. J.* 31 (8), 795–805.
- Flegg, A.T., Webber, C.D., Elliott, M.V., 1995. On the appropriate use of location quotients in generating regional input-output tables. *Reg. Stud.* 29, 547–561.
- Fontagné, L., Freudenberg, M., 1997. Intra-industry trade: methodological issues reconsidered. *CEPII Work. Pap.* 01, 97.
- Foray, D., Eichler, M., Keller, M., 2021. Smart specialization strategies—insights gained from a unique European policy experiment on innovation and industrial policy design. *Rev. Evolut. Political Econ.* 2, 83–103.
- Fournier Gabela, J.G., 2020. On the accuracy of gravity-ras approaches used for inter-regional trade estimation: evidence using the 2005 inter-regional input-output table of japan. *Econ. Syst. Res.* 32 (4).
- Franco-Bedoya, S., Frohm, E., 2022. Reduced 'border effects', free trade agreements and international trade. *World Econ.* 45 (4), 1112–1139.
- Gil-Pareja, L., Llorca-Vivero, R., Martínez-Serrano, J.A., 2005. The border effect in Spain: Regional and national estimation. *Rev. Int. Econ.* 13 (5), 969–985.
- Glejser H. (1975). "Our experience with interregional models for the Belgium, the U.S., Italy and West Germany" mimeo.
- Glejser, H., Jacquemin, J.C., Viaene, J.M., 1976. A method to estimate interregional trade flows from price equations. *Rech. Économiques De. Louvain / Louvain Econ. Rev.* 42 (3), 255–259.
- Glick, R., 2017. Currency unions and regional trade agreements: emu and eu effects on trade. *Comp. Econ. Stud.*
- Golan, Amos, Judge, George, Robinson, Sherman, 1994. Recovering information from incomplete or partial multisectoral economic data. *Rev. Econ. Stat.* 76, 541–549.
- Grimwade, N., 2013. *Theory of Economic Integration: A Review*. The New Palgrave Dictionary of Economics. Palgrave Macmillan, London.
- Guedidi, I., Baghdadi, L., Martínez-Zarzoso, I., 2024. Trade facilitation in global value chains: assessing the role of maritime connectivity and trading across borders. *J. Int. Trade Econ. Dev.* 34 (2), 309–339.
- Harrigan, F., Buchanan, I., 1984. A quadratic programming approach to input-output estimation and simulation. *J. Reg. Sci.* 24, 339–358.
- Head, K., Mayer, T., 2014. Gravity equations: workhorse, toolkit, and cookbook. *Handb. Int. Econ.* 4, 131–195.
- Hegyí, F.B., Guzzo, F., Perianez-Forte, I., Giannele, C., 2021. The smart specialisation policy experience: perspective of national and regional authorities (No. JRC123918). *J. Res. Cent.*

- Helpman, E., 1981. International trade in the presence of product differentiation, economies of scale and monopolistic competition. *J. Int. Econ.* 11, 305–340.
- Helpman, E., Krugman, P., 1985. Market structure and foreign trade: increasing returns, imperfect competition and the international economy. MIT Press, Cambridge, MA.
- Helpman, E., Melitz, M., Rubinstein, Y., 2008. Estimating trade flows: trading partners and trading volumes. *Q. J. Econ.* 123 (2), 441–487.
- Herijanto, W., Thorpe, N., 2005. Developing the singly constrained gravity model for application in developing countries. *J. East. Asia Soc. Transp. Stud.* 6, 1708–1723.
- Houeninv, Toussaint, Sédédji, Philippe, 2019. Driving factors of intra-regional trade in agricultural goods: the case of west african economic and monetary union. *Adv. Afr. Econ. Soc. Political Dev.*
- Hübler, M., 2016. A new trade network theory: What economists can learn from engineers. *J. Econ. Model.* 55, 115–126.
- Illing, H., 2025. Crossing borders: labor market effects of european integration. *J. Hum. Resour.*
- Isard, W., 1954. Location theory and trade theory: short-run analysis. *Q. J. Econ.* 68 (2), 305–320.
- Jardon, C.M., Martinez-Cobas, X., Shakina, E., 2024. Human capital and border effect: the case of Minho River area. *Pap. Reg. Sci.* 103 (4), 100035.
- Jošić, H., Bašić, M., 2021. Trade creation and trade diversion effects from croatia's cefta and eu membership. *Ekonom. Pregl.* 72 (4).
- Kabir, M., Salim, R., Al-Mawali, N., 2017. The gravity model and trade flows: recent developments in econometric modeling and empirical evidence. *Econ. Anal. Policy.*
- Kali, R., Reyes, Javier, 2007. The architecture of globalization: a network approach to international economic integration. *J. Int. Bus. Stud.* 38 (4), 595–620.
- Kavalov, B., Kucas, A., Batista, E., Silva, F., Kompil, M., Aurambout, J., Lavalle, C., 2019. A Drive Time-Based Definition of Cross-Border Regions and Analysis of Population Trends, EUR 29859 EN. Publications Office of the European Union, Luxembourg.
- Kim, K., Ferrante, C., Kogler, D.F., 2024. Smart specialisation strategies and regional knowledge spaces: how to bridge vision and reality. *Reg. Stud.* 58 (12), 2501–2517.
- Krugman, P., 1991. Geography and Trade. MIT Press, Cambridge, MA.
- Leka, D., Jusufi, G., 2024. The stabilization and association agreements in the western balkans as a tool for trade promotion and regional reconciliation. *Corp. Law Gov. Rev.* 6 (1), 38–48.
- Laguna, J.D. (Ed.), 2024. Ninth report on economic, social and territorial cohesion. Publications Office of the European Union.
- Leka, D., Daku, S., Jusufi, G., 2022. Regional cooperation and free trade agreements in Western Balkans: Opportunities and obstacles. *Int. J. Sustain. Dev. Plan.* 17.
- Leontief, W.W., 1936. Quantitative input and output relations in the economic systems of the United States. *Rev. Econ. Stat.* 18 (3), 105–125.
- Lipps, J., Schraff, D., 2021. Regional inequality and institutional trust in Europe. *Eur. J. Political Res.* 60, 892–913.
- Llano, C., 2004. The interregional trade in the context of a multiregional input-output model for Opening the interregional trade "black box": The c-interreg database for the spanish economy (1995–2005)". *Int. Reg. Sci. Rev.* 33 (3), 302–337.
- Llano, C., Esteban, A., Pérez, J., Pulido, A., 2010. Opening the Interregional Trade "Black Box": The C-Interreg Database for the Spanish Economy (1995–2005). *International Regional Science Review* 33 (3), 302–337.
- Lucas, R., 1988. On the mechanics of economic development. *J. Monet. Econ.* 22, 3–42.
- Lyzun, M., Vitálišová, K., Boršeková, K., 2024. Transformation of trade flows between the EU and Ukraine in the conditions of increasing security risks. *J. Eur. Econ.*
- Malkowski, A., Brelik, A., Malkowska, A., 2024. Cross-border dynamics and local growth: the Polish-Ukrainian border region as a case study. *Eur. Res. Stud. J.* XXVII (4), 584–599.
- Marques, H., Metcalf, H., 2005. What determines sectoral trade in the enlarged EU? *Rev. Dev. Econ.* 9, 197–231.
- Martínez-Zarzoso, Inmaculada; Márquez-Ramos, Laura (2007) "The effect of trade facilitation on sectoral trade". Discussion papers, Ibero America Institute for Economic Research, 167.
- Mayer, T., Vicard, V., Zignago, S., 2019. The cost of non-europe, revisited*. *Econ. Policy* 34 (98), 145–199.
- McCallum, J., 1995. National Borders Matter: Canada-U.S. Regional Trade Patterns. *Am. Econ. Rev.* 85 (3), 615–623.
- Medeiros, E. (2018). *European Territorial Cooperation: Theoretical and Empirical Approaches to the Process and Impacts of Cross-Border and Transnational Cooperation in Europe*. Springer, Cham.
- Melitz, M.J., 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71 (6), 1695–1725.
- Melitz, M.J., Ottaviano, Giancarlo I.P., 2008. Market size, trade, and Productivity. *Rev. Econ. Stud.* 75 (1), 295–316.
- Miller, R.E., Blair, P.D., 2009. Input-output analysis: foundations and extensions. Cambridge university press.
- Müller, F., 2016. Economic aspects of the european integration: a positive step. *Eur. Econ. Macroecon. Monet. Econ. J.*
- Nach, M., Nwadi, R., 2024. BRICS economic integration: Prospects and challenges. *South Afr. J. Int. Aff.* 31 (2), 151–166.
- Nagy, E.G.O.N., 2006. Regional disparities along the Romanian-Hungarian border region. *Rom. Rev. Reg. Stud.* 2 (2), 40–52.
- Nauwelaers, C., Maguire, K., Marsan, G.A., 2013. case Oresund (Den. Swed.) *Reg. Innov. Collab. Across Bord.*
- Nitsch, V., Wolf, N., 2013. Tear down this wall: on the persistence of borders in trade. *Can. J. Econ./Rev. can. econ.* 46 (1), 154–179.
- Nordås, H., Kox, H., 2009. Quantifying Regulatory Barriers to Services Trade. OECD Trade Policy. OECD Publishing, Paris.
- Novak, Anatolii, Pravdyvets, Oleksander, Chornyi, Oleksandr, Sumbaieva, Liudmyla, AkiMova, LyudMila, Akimov, Oleksandr, 2022. Financial and Economic Security in the Field of Financial Markets at the Stage of European Integration. *Int. J. Prof. Bus. Rev.* 7.
- OECD (2013). *Regions and Innovation: Collaborating Across Borders*. OECD Reviews of Regional Innovation. <https://doi.org/10.1787/9789264205307-en>.
- OECD (2013b), *Road Connectivity and the Border Effect. Evidence from Europe*, OECD Economics Department Working Papers.
- OECD. 2024. *Building more resilient cross-border regions*.
- OECD (2024), *Building More Resilient Cross-border Regions. Considerations in Governance and Partnerships*. OECD Multi-level Governance Studies.
- Oesingmann, Katrin, 2022. The determinants of air cargo flows and the role of multinational agreements: an empirical comparison with trade and Air Passenger Flows. *World Econ.* 45 (8).
- Paas, T., Tafenu, E., 2005. Regional trade clusters in promoting eastward enlargement of european union. *Transit. Stud. Rev.* 12, 77–90.
- Padaki, Ramith, Goel, Mridula, 2015. A gravity model analysis of effects of regional economic integration on factor flows. *J. Econ. Coop. Dev.* 36 (4).
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., et al., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 372 (71).
- Patandianan, Marly Valenti, Shibusawa, Hiroyuki, 2020. Impacts of disaster on the inbound tourism economy in Kyushu, Japan: a demand side analysis. In: *Asia-Pacific Journal of Regional Science*, 4. Springer, pp. 759–793.
- Perkmann, Markus, 2003. Cross-border regions in Europe: Significance and drivers of regional cross-border co-operation. *Eur. Urban Reg. Stud.* 10 (2), 153–171.
- Persyn, Damiaan, Torfs, Wouter, 2016. A gravity equation for commuting with an application to estimating regional border effects in Belgium. *J. Econ.* 16 (1).
- Potluka, O., Schubnell, L., 2023. Non-profit Organizations and Territorial Cohesion: The Case of Cross-Border Collaboration. In: Medeiros, E. (Ed.), *Public Policies for Territorial Cohesion*. The Urban Book Series. Springer, Cham.
- Potluka, O., Schubnell, L., Medeiros, E., Weller, M., 2025. The role of non-profit organizations in territorial cohesion in cross-border regions. *Reg. Sci. Policy Pract.*
- Pöyhönen, P., 1963. A Tentative Model for the Volume of Trade between Countries. *Weltwirtschaftliches Arch.* 90, 93–100.
- Proença, I., Sperlich, S., Savaşçı, D., 2015. Semi-mixed effects gravity models for bilateral trade. *Empir. Econ.* 48, 361–387.
- Radil, S.M., Ptak, T., 2024. Borders, Boundaries, and Borderlands. In: Warf, B. (Ed.), *The Encyclopedia of Human Geography*. Springer, Cham.
- Ravenstein, E.G., 1885. The Laws of Migration. *J. Stat. Soc. Lond.* 48 (2), 167–235.
- Redding, Stephen, Venables, J., Anthony, 2004. Economic geography and international inequality. *J. Int. Econ.* 62 (1), 53–82.
- Riache, Siham, Louail, Bilal, Belouard, Ali Nabil, 2020. The Relationship of Arab Economic Integration to Foreign Direct Investment in the Arab Countries: Impact Analysis Using the Augmented Gravity Model. *Int. J. Adv. Appl. Sci.* 7 (4).
- Rodríguez-Pose, A., 2020. Institutions and the fortunes of territories. *Reg. Sci. Policy Pract.* 12 (3), 371–386.
- Sargento, A.L., Nogueira Ramos, P., 2003. Estim. Trade flows Port. Reg. Using Input-Output Approach.
- Sargento, A.L.M., Ramos, P.N., Hewings, G.J.D., 2012. Inter-regional trade flow estimation through non-survey models: An empirical assessment. *Econ. Syst. Res.* 24 (2), 173–193.
- Sarker, Rakhal, Jayasinghe, Sampath, 2007. Regional Trade Agreements and Trade in Agri-Food Products: Evidence for the European Union from Gravity Modeling Using Disaggregated Data. *Agric. Econ.* 37 (1).
- Schlitte, F., Paas, T., 2008. Regional Income Inequality and Convergence Processes in the EU-25. *Sci. Regionali* 2, 29–49.
- Shevtsova, Y., Díaz-Lanchas, J., Persyn, D., Mandras, G., 2025. Trade spillover effects of transport infrastructure investments: a structural gravity analysis for EU regions. *Reg. Stud.* 59 (1), 2441231.
- Silva, J.M.C.S., Tenreiro, S., 2006. The Log of Gravity. *Rev. Econ. Stat.* 88 (4), 641–658.
- Silva, J.M.C.S., Tenreiro, S., 2011. Further simulation evidence on the performance of the Poisson pseudo-maximum likelihood estimator. *Rev. Econ. Stat.* 112 (2), 220–222.
- Spolaore, E., Wacziarg, R., 2005. "Borders and Growth. In: *Journal of Economic Growth*, 10. Springer, pp. 331–386.
- Stack, M.M., 2009. "Regional Integration and Trade: Controlling for Varying Degrees of Heterogeneity in the Gravity Model. *World Econ.* 32, 772–789.
- Stack, M.M., Bliss, M., 2020. EU economic integration agreements, Brexit and trade. *Rev. World Econ. / Weltwirtschaftliches Arch.* 156 (3), 443–473.
- Stack, M.M., Pentecost, E., 2011. "Regional integration and trade: A panel cointegration approach to estimating the gravity model. *J. Int. Trade Econ. Dev.* 20 (1), 53–65.
- Szejgic-Kolenda, B., Duma, P., 2020. Trade linkages within the Baltic Sea region - towards regional integration. *Przegląd. Geogr.* 92 (4), 609–630.
- Talebain, S., Benzie, M., Harris, H., Jarzabek, L., Magnuszewski, P., Carter, T.R., Obermeister, N., 2025. A conceptual framework for responding to cross-border climate change impacts. *Environ. Sci. Policy* 163.
- Tinbergen, J., 1962. An Analysis of World Trade Flows. *Shap. World Econ.* 3, 1–117.
- Tsiopa, A., Gerber, P., Caruso, G., 2024. Framing the cross-border commuting literature: a systematic review and bibliographic analysis. *Transp. Rev.* 44 (4), 889–911.

- Vedres, B., Nordlund, C., 2018. Disembedded Openness: Inequalities in European Economic Integration at the Sectoral Level. *St Comp. Int Dev.* 53, 169–195.
- Walz, U., 1998. Does an enlargement of a common market stimulate growth and convergence? *J. Int. Econ.* 45 (2), 297–321.
- Wang, B., Pu, Y., Li, S., Xu, L., 2021. The influence of regional preferential trade agreements on international manufacturing trade in value-added: Based on the complex network method. *PLoS ONE* 16 (2).
- Wang, C., Wu, J., Liu, X., 2022. High-speed rail and urban innovation: based on the perspective of labor mobility. *J. Asia Pac. Econ.* 29 (2), 837–862.
- Wilson, A.G., 1971. A family of spatial interaction models, and associated developments. *Environment Plan. A Econ. Space* 3 (1), 1–32.
- Wolodin, D., 2024. Twenty years of Poland-Ukraine cross-border cooperation: reflections and responses in the wake of the Russian military aggression. *SpaceSoc. Econ.* (35), 75–95.
- Zaninovic, Petra Adelajda, Zajc Kejzar, Katja, Pavlic Skender, Helga, 2024. Assessing the Effects of Hard and Soft Infrastructure on Traditional vs Supply-Chain Trade: The Case of Central and Eastern EU Member States (CEMS). *Appl. Econ.* 56 (3).