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Bilateral trade and voluntary environmental standards: Insights from ISO 14001 certification

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ABSTRACT

This paper examines the relationship between ISO 14001 certification intensity and bilateral trade flows within a structural gravity framework. Exploiting variation between intra-national and international trade flows, we estimate the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade in the presence of high-dimensional fixed effects. Using a balanced panel of 38 OECD countries over the period 2000–2019, we find a positive estimated differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade. The estimated coefficients imply that a 1% increase in certification intensity corresponds to approximately 0.05% higher international trade relative to intra-national trade within the maintained structural-gravity specification. The estimated differential effect is slightly larger when lagged certification intensity is used, a pattern consistent with gradual adjustment as firms implement environmental management practices, signal compliance to foreign partners, and adjust their international market relationships. The positive estimate remains robust across alternative cardinal definitions of certification intensity, FE specifications, additional bilateral controls, crisis-period checks, and alternative country samples, including a global sample of 198 countries. Sectoral analysis reveals substantial heterogeneity: the estimated differential effect is strongest in agriculture and manufacturing, smaller in services, and not statistically significant in mining and energy. These findings highlight substantial sectoral heterogeneity in the trade-related effects of voluntary environmental standards.

1. Introduction

The reduction of trade barriers and restrictions through various global initiatives has facilitated the creation of cross-border production and distribution networks, resulting in increased international trade. This expansion is reflected in growing bilateral flows of goods and services and in increased cross-border exchanges of capital, technology, and knowledge (Wu et al., 2019; Jiang et al., 2020).

Nevertheless, these mutually beneficial partnership arrangements are often constrained by differences in institutional and regulatory frameworks between the two trading partners. Challenges arise from various operational conditions between countries, such as the specific technical characteristics of a product related to safety, security, and environmental issues. Moreover, the differences arising from cultural, geographic, economic, and administrative requirements involved in operating in foreign markets create obstacles and disadvantage organisations when they internationalise (Drori et al., 2023). These external factors often create uncertainty and incur additional costs, discouraging deeper commercial ties. Conversely, operational alignment and compatibility

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among traders can help reduce such cross-border frictions, including those associated with non-tariff measures (NTMs) (Prahalad and Doz, 1987). In this regard, adopting and consistently applying international standards can contribute to harmonising expectations and facilitating mutual recognition of regulations (Blind et al., 2024).

Theoretically, standards serve as an important mechanism for coordinating activities and are essential instruments for regulating processes (Nadvi and Wältring, 2004). From an institutional theory perspective, they are defined as a specific form of institution that determines the specifications of processes, products, and services throughout a company's value chain and across entire markets (Blind et al., 2024).[1] Notably, they ensure that products and services meet specific quality criteria, which helps build trust among consumers and other stakeholders. In this context, standards facilitate coordination across various value chain phases (Blind and Müller, 2020). They also align diverse suppliers with uniform rules, enhancing collaboration and interoperability, which fosters a more cohesive market environment. Moreover, they provide a common language that enhances cross-border collaboration and minimises uncertainty (David, 1987; Roth and Morrison, 1990).

Despite the growing importance of standards, some scholars have questioned their benefits in international trade (Beghin et al., 2015; Zahoor et al., 2023). Whether standards operate through trade-facilitating or trade-restricting channels remains a complex and context-dependent issue rather than a settled phenomenon (Swinnen and Vandemoortele, 2012; Duan et al., 2021). This is because the evolution of standards and their interaction with stakeholders, such as businesses, regulatory organisations, and consumers, mainly depends on the attributes and characteristics of the standards (Wiegmann et al., 2017).[2] Standards differ from each other in the mechanism they employ (cooperation or competition), the actors involved (public or private), and the timing of process development or diffusion (Blind et al., 2018a). Moreover, standards reflect various approaches with different economic and cultural priorities and different levels of technological advancement (Tamini and Sorgho, 2018). This implies that standardisation can take multiple forms, each influenced by specific dynamics and interactions. The evolution and outcomes of these processes are shaped by the stakeholders involved (Wiegmann et al., 2017).

Several authors have studied the role of standards in trade (Swann, 2010; Kim, 2012; Clougherty and Grajek, 2014; Ni et al., 2022; Zahoor et al., 2023; Sun et al., 2023). However, many existing empirical studies focus on export competitiveness (Potoski and Prakash, 2009) of particular country groups (Martincus et al., 2010), or specific economic sectors (Ni et al., 2022; Sun et al., 2023), leaving limited evidence on the outcomes of a specific standard in a broad cross-country bilateral setting. Moreover, while standards have the potential to shape trade relationships between countries (Wu et al., 2019), few studies examine the effects of standards on bilateral trade flows (Blind, 2001; Siroën, 2016).

The diffusion of standards may affect both exporting and importing countries. It may enhance exporter competitiveness, while their diffusion in destination markets may facilitate or hinder exports depending on whether information benefits outweigh compliance costs (Clougherty and Grajek, 2014; Santeramo and Lamonaca, 2019). One relevant mechanism is the ability of standards to reduce information asymmetries between foreign buyers and suppliers by providing a common and credible signal of product, process, or management quality (Hayat and Lohano, 2024). This is particularly relevant in international markets, where firms often have limited information about the reliability and practices of potential partners. Standards also lower transaction costs by harmonising procedures, documentation, and expectations across countries, making it easier for firms to enter and maintain trade relationships. They may facilitate participation in global value chains by reducing fixed market-entry costs, especially when lead organisations require suppliers to comply with recognised certification systems (Blind et al., 2018b). However, standards can also have restrictive effects if compliance requires costly adjustments, particularly for firms in countries or sectors with weaker certification capacity (World Trade Organization, 2012; International Organization for Standardization, 2019a).

Within this framework, our work aims to examine the relationship between ISO 14001 certification intensity and bilateral trade. Among voluntary standards, ISO 14001, the international standard for environmental management systems (EMS), has diffused rapidly. ISO 14001 is a voluntary, commitment-based standard[3] that aims to promote environmentally sustainable practices among organisations. The literature suggests that EMS standards can help organisations improve their environmental performance (Arimura et al., 2016; Camilleri, 2022), reduce information asymmetries (Sartor et al., 2019), and overcome trade barriers related to environmental regulations (Liu et al., 2020). However, while some research acknowledges the role of ISO 14001 in export outcomes (Sam and Song, 2022; Sun et al., 2023), the relationship between EMS certification and bilateral trade flows remains underexplored.

This paper contributes to the literature in three main respects. First, it provides broad cross-country evidence on the relationship between ISO 14001 certification intensity and bilateral trade within a theory-consistent structural-gravity framework. Second, it brings a country-specific measure of environmental certification into a framework that distinguishes international from intra-national trade, allowing the trade-related differential associated with certification intensity to be examined while accounting for the main structural determinants of bilateral trade. Third, the paper investigates whether this relationship differs across broad economic sectors and assesses its stability across alternative measures of certification intensity and country samples.

To empirically analyse the relationship between ISO 14001 certification intensity and bilateral trade flows, we employ a theory-consistent structural gravity model estimated on a balanced panel dataset covering the period 2000–2019. The empirical strategy exploits the availability of both intra-national and international trade flows. Following Beverelli et al. (2024), we identify the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade within

[1] More broadly, Hoffman (1999, p. 351) defines institutions as "the rules, norms, and beliefs that describe reality for the organisation".

[2] Standards can be commitment-based, market-based, or government-based and may be applied nationally or internationally (Wiegmann et al., 2017).

[3] Voluntary standards are commitments or programmes proposed by associations, firms, or other institutions that organisations may choose to adopt and that do not impose mandatory legal requirements (Blackman et al., 2010).

the structural-gravity specification by interacting certification intensity with an international-border indicator. This approach allows us to estimate this differential effect while retaining exporter-year, importer-year, and country-pair fixed effects (FEs).

We focus our baseline estimation on a sample of 38 OECD countries. These countries account for a substantial share of global ISO 14001 certifications (see Fig. 1 in the Appendix) and exhibit substantial variation in certification intensity over time. This sample choice improves comparability across relatively similar institutional and economic environments while preserving sufficient variation for identification.

The estimated results indicate a positive and statistically significant differential effect of ISO 14001 certification intensity on international trade relative to intra-national trade. Quantitatively, the baseline coefficient of 0.051 implies that a 1% increase in exporter ISO 14001 certification intensity corresponds to approximately 0.051% higher international trade relative to intra-national trade. The lagged estimate is slightly larger, a pattern consistent with gradual adjustment as certification-related practices and market relationships take time to affect cross-border trade.

To assess the robustness of these findings, we conduct a wide range of sensitivity analyses. The positive estimated differential effect remains statistically significant when ISO 14001 certification intensity is scaled by initial GDP or exporter output, entered as raw certificates per million inhabitants, or transformed using the inverse hyperbolic sine. It is also robust to alternative FE structures, additional bilateral controls, crisis-period checks, lagged bilateral trade controls, sample exclusions, and alternative country samples. The within-year rank specification provides an alternative ordinal measure of certification intensity, while exporter–importer complementarity is examined in a separate diagnostic specification. Neither provides statistically significant evidence for those specific dimensions. Extending the analysis to a global sample of 198 countries and to the EU-27 and EU-15 subsamples produces positive and statistically significant estimates, suggesting that the results generalise beyond the baseline OECD sample.

We further examine sectoral heterogeneity by estimating the model separately for agriculture, manufacturing, mining and energy, and services. Because ISO 14001 certification data are observed at the country-year level, this analysis does not measure sector-specific certification intensity; rather, it estimates whether the differential effect of exporter-level certification intensity varies across sector-specific trade flows. The estimated differential effect is largest in agriculture and manufacturing, smaller in services, and not statistically significant in mining and energy. This qualitative sectoral pattern remains unchanged when certification intensity is measured using raw certificates per million inhabitants, the inverse hyperbolic sine transformation, or measures scaled by initial GDP or exporter output, and it is broadly confirmed in the global sample of 198 countries. The results suggest that ISO 14001 certification is particularly relevant in sectors where environmental management, quality assurance, and compliance with international market requirements are closely linked to production and supply-chain organisation.

The rest of this study is structured as follows. Section 2 conceptualises ISO 14001 certification and reviews the literature on environmental standards and international trade. Section 3 presents the empirical strategy and discusses identification and estimation. Section 4 describes the data and variable construction. Section 5 reports the baseline results, robustness checks, and sectoral heterogeneity analysis. Section 6 concludes.

2. Literature review

2.1. Environmental management system overview

The EMS framework offers a comprehensive approach to regulating and mitigating the environmental impacts arising from industrial production (Ahmed and Mathrani, 2023). Developed by the International Organization for Standardization (ISO), this framework is both process-oriented and performance-based, making it adaptable across diverse industry sectors and geographic contexts (Dissou, 2005). Among the various EMS standards, the ISO 14000 series, introduced in 1996, was the first to address business needs in environmental management. Within this series, ISO 14001 has emerged as the most widely recognised and globally implemented standard (Liu et al., 2020).

ISO 14001 is a voluntary, commitment-based standard, and it does not mandate specific environmental targets or objectives as prerequisites for certification. In addition, it does not enforce specific pollution-prevention or impact-reduction measures (Heras-Saizarbitoria and Boiral, 2013). It sets out the requirements for establishing, implementing, maintaining, and continually improving an EMS. In substance, it provides a flexible managerial framework that enables organisations to develop and maintain an EMS in their operational context, supported by ongoing environmental audits (Ahmed et al., 2021).

Structurally, ISO 14001 is organised around the Plan-Do-Check-Act cycle, which comprises seven substantive implementation stages. Specifically, in the first stage, which focuses on understanding the organisation's structure, the firm must identify internal and external issues relevant to its EMS, determine the needs and expectations of interested parties, define the scope of the EMS, and establish the system. The second stage concerns leadership characteristics, in which top management must demonstrate commitment and establish an environmental policy. In the third stage, related to planning activities, the organisation must identify environmental aspects and impacts, determine risks and opportunities, identify compliance obligations, and set environmental objectives and action plans. In the fourth and fifth stages, which include support and operation activities, the organisation must provide resources, ensure competence and awareness, establish operational controls, and consider a life-cycle perspective. The sixth stage concerns performance evaluation. The EMS must be continuously monitored, compliance must be evaluated, and management reviews must be conducted. Finally, in the improvement stage, organisations must address nonconformities, take corrective action as necessary, and continually improve the EMS (International Organization for Standardization, 2017).

Following implementation of an EMS, organisations typically engage in an external certification process administered by an accredited certification body. This process typically involves a two-stage audit that assesses the EMS's compliance with the standard's

criteria. Certification is generally maintained through a three-year cycle, during which periodic surveillance audits are conducted to ensure continued compliance and effectiveness of the EMS (International Organization for Standardization, 2019b). These surveillance audits typically occur annually and help organisations identify areas for improvement, ensuring that the EMS adapts to evolving environmental standards and practices (International Organization for Standardization, 2026).

2.2. Standards, environmental certification, and international trade

The relationship between standards and international trade has long been a subject of scholarly debate because of their potentially dual effects. This duality can be understood within the broader literature on NTMs (Santeramo and Lamonaca, 2019). NTMs are not intrinsically protectionist like "non-tariff barriers"; rather, they may either obstruct or facilitate international trade, depending on the underlying benefit-cost trade-off (Xiong and Beghin, 2014; Swinnen, 2016). According to United Nations Conference on Trade and Development (UNCTAD) (2012), NTMs are policy measures other than ordinary tariffs that may affect traded quantities or prices while also performing a corrective function by addressing market imperfections, such as information asymmetries and negative externalities. In the NTMs literature, the dual effect of voluntary standards may be understood as two sides of the same coordination process: diffusion creates shared expectations and reduces uncertainty, but it may also increase compliance costs and the cost of remaining outside the certification system.

The existing literature clearly shows that standardisation is a crucial process for organising activities and an important instrument for coordinating processes. It allows organisations to ensure uniformity in processes and products, enhancing efficiency and improving quality. When standards are internationally recognised and widely diffused, they can reduce uncertainty in cross-border transactions. Under signalling theory, standards may be interpreted as market devices through which organisations convey credible information about otherwise difficult-to-observe attributes, such as recognised safety or environmental performance, thereby reducing information asymmetries and supporting market access (Spence, 1973; Connelly et al., 2011). Research by Blyde (2021) suggests that obtaining certification increases an organisation's probability of becoming an exporter rather than its export volume, implying that certification facilitates entry into export markets by reducing information frictions. Furthermore, Sun et al. (2023) claim that voluntary standards improve the accuracy and transparency of information, creating export opportunities for foreign firms and reducing the cost of gathering information. Consistent with this trade-facilitating perspective, Bemelmans et al. (2023) find that voluntary sustainability standards generally improve export performance, although their effects vary across commodities and trading partners. Standards may also serve as a powerful emblem of responsibility, enhancing brand image in international markets. By signalling a commitment to quality and sustainability, they can help organisations build "reputation wealth" (Fombrun, 1996) and demonstrate their commitment to stakeholders and regulators (McGuire, 2014).

Another strand of literature emphasises the potentially restrictive effects of standards, arguing that they may fragment trade by increasing market-access costs and disproportionately burdening foreign producers (Zahoor et al., 2023). More broadly, technical and regulatory standards, examined within the framework of NTMs, may alter traded quantities, prices, and the conditions under which firms access foreign markets. According to Santeramo and Lamonaca (2019), although these measures offer several advantages to consumers, such as mitigating information asymmetries and externalities, enhancing trust, cutting transaction costs, and boosting demand, their adoption can impose both fixed and variable compliance costs on producers and exporters. The adoption of standards frequently entails considerable initial expenditures for certification, monitoring, process restructuring, documentation, and the development of managerial capabilities (Wayoro et al., 2025). These costs disproportionately burden smaller and less productive organisations, potentially excluding them from international markets (Portugal-Perez et al., 2009). Schmidt and Steingress (2022) show that the largest firms in the upper part of the size distribution increase their export sales following the introduction of harmonised standards. This indicates a selective effect whereby standards may reallocate trade opportunities towards organisations that are better equipped to comply and disadvantage firms and countries with weaker technical and institutional capacities (Chen et al., 2008; Allur et al., 2014; Ni et al., 2022).

Regarding ISO 14001, various researchers have extensively analysed the drivers that motivate organisations to adopt this voluntary standard. Several studies show that ethical considerations, particularly those related to the environmental sensitivity of a firm's management, encourage its adoption (Sartor et al., 2019). These motivations are often reinforced by pressure from domestic and international consumers, who increasingly demand more environmentally friendly products. Moreover, regulatory requirements may encourage organisations to implement environmentally responsible business practices and integrate EMS practices into their core activities (Fitzmaurice, 2018). Beyond managerial sensitivity and regulatory pressures, a more recent strand of research emphasises the role of ISO 14001 in creating shared value through improvements in financial performance and competitiveness (Shaharudin et al., 2017; Miroshnychenko et al., 2017; Vijayvargy et al., 2017; Su et al., 2018; Hayat and Lohano, 2024).

Although ISO 14001 is not a protectionist instrument in the strict sense, because governments generally do not require certification as a legal condition for market access, it may function as a restrictive private-market requirement. As the standard becomes more widely adopted within a market or supply chain, lead firms and multinational buyers may start to require, or at least strongly favour, suppliers that are certified (Darnall, 2006; Delmas and Montiel, 2009). Certification may therefore become a shared market convention and a *de facto* condition for entering or maintaining particular commercial relationships. This coordination mechanism is especially relevant when firms deal with foreign or geographically distant buyers who cannot directly observe their environmental management practices (King et al., 2005). It may also be reinforced when ISO 14001 is already widely adopted in major export markets (Prakash and Potoski, 2006). Consequently, although firms remain formally free not to adopt the standard, non-certified firms may face exclusion or a competitive disadvantage within particular markets and supply chains. This disadvantage may be especially pronounced for firms with limited resources and organisational capabilities, given the costs of adopting and

maintaining certification (Darnall and Edwards, 2006). ISO 14001 may therefore produce an effect similar to a market-entry barrier through private coordination and unequal capacities to comply, rather than through formal regulatory protectionism.

While previous studies have examined the adoption, environmental implications, and export-related outcomes of ISO 14001, the evidence remains largely based on particular countries, sectors, or firm-level samples (Xu et al., 2018; Wang and Zhao, 2020; Sam and Song, 2022; Sun et al., 2023). This unresolved ambiguity points to an important gap in the literature and motivates a broader bilateral analysis of the differential effect of country-level ISO 14001 certification intensity on international trade relative to intra-national trade.

3. Empirical strategy

To estimate the differential effect of ISO 14001 certification intensity on bilateral trade flows among 38 OECD countries over the period 2000–2019, we employ a theoretically grounded gravity model that is consistent with the structural gravity framework of Anderson and Van Wincoop (2003).[4] Our specification incorporates recent advances in the empirical gravity literature to ensure proper identification and consistent estimation.[5]

A central empirical challenge in gravity models is the identification of country-specific variables in the presence of exporter-year and importer-year FEs, which absorb all time-varying country-level characteristics. As a result, variables such as ISO 14001 certification intensity cannot be directly identified. To overcome this limitation, we follow the methodology proposed by Beverelli et al. (2024), which exploits the variation between intra-national and international trade flows.

Specifically, identification is achieved by interacting country-specific ISO 14001 certification intensity with an international-border indicator equal to one for cross-border flows and zero for intra-national flows.[6] This approach allows us to estimate the differential effect of ISO 14001 certification on international trade relative to intra-national trade while maintaining a fully specified structural gravity framework. Freeman et al. (2025) develop a broader two-stage structural-gravity framework that nests the specification of Beverelli et al. (2024). Their framework separates the uniform effect of a country-specific characteristic, common to intra-national and international trade, from its differential effect on international relative to intra-national trade; combining the two components yields the full effect of the country-specific characteristics on trade. Because our parameter of interest is the differential effect of exporter ISO 14001 certification intensity, we retain the specification of Beverelli et al. (2024).

Our baseline econometric specification is given by

$$X_{ij,t} = \exp\left[\beta\left(ISO14_{i,t} \times INT_{ij}\right) + \gamma_{i,t} + \delta_{j,t} + \mu_{ij}\right]\varepsilon_{ij,t}, \tag{1}$$

where $X_{ij,t}$ denotes the nominal trade flows (Baldwin and Taglioni, 2006) from country i to j at time t, including both international ($i \neq j$) and intra-national ($i = j$) trade. The inclusion of domestic trade flows is essential for identification, as it allows us to distinguish between the effects of country-specific characteristics on internal versus cross-border trade (Yotov, 2022).[7]

The variable $ISO14_{i,t}$ measures exporter-specific ISO 14001 certification intensity and captures the extent of adoption of environmental management standards in the exporting country. A detailed description of its construction is provided in Section 4. Since $ISO14_{i,t}$ varies only at the exporter-year level, its direct effect is absorbed by exporter-year FEs. However, when interacted with the international-border indicator, the variable takes the value zero for intra-national trade flows and equals exporter ISO 14001 certification intensity for international trade flows. This differential variation between domestic and cross-border flows is not absorbed by FEs and identifies the coefficient of interest.

The indicator variable INT_{ij} is an international-border indicator that takes the value one for cross-border trade flows and zero for intra-national trade flows. The interaction term $ISO14_{i,t} \times INT_{ij}$ is our key variable of interest. The coefficient β captures the differential effect of exporter ISO 14001 certification intensity on international trade relative to intra-national trade, conditional on the FEs included in Eq. (1). In other words, it measures how cross-border trade changes relative to domestic trade when exporter ISO 14001 certification intensity changes.

Following Nizalova and Murtazashvili (2016), Beverelli et al. (2024) further show that this interaction-based strategy can address concerns arising from the potentially endogenous country-specific variables in structural-gravity settings under the maintained assumption that the variable interacted with the country-specific factor is exogenous. In our application, we treat the international-border indicator as predetermined by the distinction between intra-national and cross-border trade. Accordingly, under the maintained assumptions of the structural-gravity model, the coefficient on $ISO14_{i,t} \times INT_{ij}$ identifies the differential effect of exporter ISO 14001 certification intensity on international trade relative to intra-national trade.[8]

Within the structural gravity framework, ISO 14001 certification intensity is treated as a country-specific characteristic whose differential effect on international relative to intra-national trade may operate through information, signalling, compliance-cost, transaction-cost, and market-access channels.

[4] See Online Appendix S1 for details on the structural gravity model of trade.

[5] For discussions of theory-consistent gravity estimation and related econometric issues, see Baldwin and Taglioni (2006), Silva and Tenreyro (2006), Head and Mayer (2014), Piermartini and Yotov (2016).

[6] The interaction term can be defined using either exporter- or importer-specific ISO 14001 certification intensity without affecting the corresponding estimates. However, it is not possible to simultaneously identify the separate effects of exporter- and importer-specific characteristics in this framework.

[7] In line with Piermartini and Yotov (2016) and Yotov (2021), inclusion of intra-national trade flows ensures theoretically consistent estimation of the gravity equation. For a literature review, see Yotov (2022).

[8] Identification is understood in the structural-model sense: the parameter is recovered under the maintained assumptions of the structural-gravity specification rather than through externally assigned treatment variation.

In the robustness analysis, we augment Eq. (1) with a vector $Z_{ij,t}$ of time-varying bilateral control variables that may affect trade flows. These include $RTA_{ij,t}$ for the presence of regional trade agreements and $Tariff_{ij,t}$ for bilateral tariffs. They also include a set of geopolitical and policy-related variables, such as $Sanction_{ij,t}$ for different types of economic sanctions: arms, military assistance, trade, financial, travel, and other sanctions; $SOFTconflict_{ij,t}$ for interstate soft conflicts; $MID_{ij,t}$ for militarised interstate disputes (MIDs) coded into the display of force, use of force and war; $State_Acts_{ij,t}$ for export and import policy instruments, trade defense instruments, NTBs, and other state acts.[9]

Our specification includes a full set of high-dimensional FEs commonly used in the empirical gravity literature to ensure robust estimation (Baldwin and Taglioni, 2006). $\gamma_{i,t}$ represents exporter-year FEs, while $\delta_{j,t}$ denotes importer-year FEs. These FEs control for the unobservable outward and inward multilateral resistance terms (MRTs) identified by Anderson and Van Wincoop (2003), as well as all observable and unobservable country-specific factors that vary over time. Country-pair FEs μ_{ij} absorb all observable and unobservable time-invariant bilateral determinants of trade costs and shift identification to within-pair variation. As discussed by Baier and Bergstrand (2007), these FEs also address the linkages between potentially endogenous trade policy variables and the multiplicative error term $\varepsilon_{ij,t}$. Standard errors are clustered at the country-pair level.

We estimate Eq. (1) using the Poisson Pseudo Maximum Likelihood (PPML) estimator, following Silva and Tenreyro (2006). Their research argues that, in the presence of heteroskedasticity, log-linearising the gravity equation may lead to inconsistent estimates. Consequently, they recommend using PPML, which addresses the shortcomings of the standard OLS estimator. Additionally, PPML naturally accommodates zero trade flows, which would otherwise be excluded in log-linear OLS specifications, potentially creating a selection bias problem (Head and Mayer, 2014). Moreover, as noted by Weidner and Zylkin (2019), PPML is one of the estimators that may provide consistent estimates in a three-way gravity specification incorporating the full set of FEs without imposing strict assumptions on the variance of the error term.

Based on these considerations, we employ balanced panel data and the PPML estimator with the full set of FEs to obtain estimates for all specifications of Eq. (1). For comparison, we also estimate both OLS and PPML under three fixed-effect (FE) structures: without FEs; with exporter-year and importer-year FEs; and with the full set of exporter-year, importer-year, and country-pair FEs (see Online Appendix S3 for details).[10]

4. Data

To perform the empirical analysis, we construct a balanced panel dataset of bilateral trade flows at the country-pair-year level over the period 2000–2019. The sample combines information from multiple sources.

Bilateral trade flows, including both international and intra-national trade, are obtained from Release 3 of the International Trade and Production Database for Estimation (ITPD-E). The ITPD-E was originally developed by Borchert et al. (2021) and, for the current analysis, we use the latest edition of the data (Larch et al., 2025). In the ITPD-E, domestic trade[11] is calculated as the difference between the (gross) value of total production and total exports for each industry. The inclusion of intra-national trade flows is essential for our empirical strategy, as it allows identification of country-specific variables through differences between domestic and cross-border trade flows. The ITPD-E provides harmonised and consistent data across countries and sectors without relying on statistical imputation, making it particularly suitable for structural gravity estimation.

Our main explanatory variable is exporter-specific ISO 14001 certification intensity. The ISO measure varies at the country-year level and is assigned to all trade flows originating from exporter i in year t. The underlying data are drawn from the 2022 edition of the ISO Survey, which reports the annual number of valid ISO 14001 certificates by country.

These observations represent certificates that are valid in a given year rather than cumulative historical certifications. Consequently, certificate counts may increase as new certifications are issued and decrease because of expiration, non-renewal, withdrawal, or changes in reporting coverage.

To obtain a measure comparable across countries, we calculate the number of certificates per million inhabitants using population data from the World Bank's World Development Indicators (WDI) and construct the following log-transformed measure of certification intensity:

$$ISO14_{i,t} = \log\left(1 + \frac{\text{Certificates}_{i,t}}{\text{Population}_{i,t}} \times 10^6\right). \tag{2}$$

Multiplication by 10^6 expresses the certificate-to-population ratio as certificates per million inhabitants rather than certificates per individual, thereby avoiding very small numerical values and providing a more interpretable unit. Population scaling adjusts absolute certificate counts for differences in country size, while the logarithmic transformation mitigates skewness, reduces the influence of extreme values, and remains well defined at zero. Accordingly, $ISO14_{i,t}$ is the logarithm of the underlying certification-intensity index, defined as one plus certificates per million inhabitants.

[9] Online Appendix S2 provides a complete list of variables, along with their definitions and data sources.

[10] As noted by Head and Mayer (2014, p. 17) "rather than selecting the Poisson PML as the single "workhorse" estimator of gravity equations, it should be used as part of a robustness-exploring ensemble that also includes OLS and Gamma PML". We considered Gamma Pseudo-Maximum Likelihood as well, but we encountered convergence issues and potential inconsistency in the presence of high-dimensional FEs; see Online Appendix S3 and Correia et al. (2019), Weidner and Zylkin (2019) for further discussion.

[11] Trade is domestic when the exporter and the importer are the same country.

This transformation yields a continuous and time-varying measure of ISO adoption that is comparable across countries and suitable for regression analysis.

Because population is not the only possible measure of economic scale, the robustness analysis also assesses alternative specifications based on initial GDP, initial exporter output, raw certificates per million inhabitants, and the inverse hyperbolic sine transformation. The construction of these alternative measures is described in Online Appendix S5.

In addition to the key explanatory variable, we also use a set of standard gravity variables that are commonly used in the empirical gravity literature. Time-invariant bilateral characteristics such as geographic distance, contiguity, common language, and colonial ties are obtained from the Centre d'Études Prospectives et d'Informations Internationales (CEPII) dyadic GeoDist database (Mayer and Zignago, 2011) and are used in the alternative specifications reported in Online Appendix S3. The data on GDP (current US dollars) are from the WDI.

We also include time-varying bilateral controls to account for policy and geopolitical factors that may influence trade flows, such as RTAs, tariffs, economic sanctions, soft conflicts, MIDs, and state acts. Data on RTAs are from Mario Larch's Regional Trade Agreements Database (Egger and Larch, 2008). Bilateral tariff data come from Feodora Teti's Global Tariff Database (GTD) (Teti, 2024), while information on bilateral economic sanctions covering trade, financial activity, arms, military assistance, travel, and other sanctions is drawn from the latest release of the Global Sanctions Database (GSDB) (Felbermayr et al., 2020; Yalcin et al., 2025). Data on interstate soft conflicts is from Taralashvili (2024, 2025), while data on militarised interstate disputes come from the dyadic MID database compiled by the Correlates of War Project (Maoz et al., 2019). The Dyadic MID database records interstate conflicts, coded as displays of force, use of force, or war. Lastly, data on state acts, which include information on export and import policy instruments, trade defense instruments, NTBs, and other types of restrictions, are from the Global Trade Alert initiative (Evenett and Fritz, 2020), which includes more than 33,000 records of state acts.

Our baseline analysis focuses on a balanced panel of 38 OECD countries over the period 2000–2019. This restriction improves comparability across countries with relatively similar institutional and economic environments while preserving substantial variation in ISO 14001 certification intensity. These countries also account for a considerable share of global ISO 14001 certification activity (see Fig. 1 in the Appendix).[12] To assess external validity and sensitivity to sample composition, we also estimate the model using the available global sample of 198 countries and the more homogeneous EU-27 and EU-15 samples.

With 38 countries observed over 20 years, the contemporaneous panel contains 28,880 country-pair-year observations. The one-year-lagged specification contains 27,436 observations.

Together, these data allow us to estimate a structurally consistent gravity model while accounting for a wide range of economic, institutional, and geopolitical determinants of trade.

5. Results

5.1. Baseline estimation results

Following the comparison of alternative estimators reported in Online Appendix S3[13] we adopt the PPML estimator with exporter-year, importer-year, and country-pair FEs as our preferred specification.

Our main variable of interest is the interaction between exporter ISO 14001 certification intensity and an international-border indicator, which captures the differential effect of ISO 14001 certification intensity on international relative to intra-national trade.

Table 1 reports the baseline estimation results for a sample of 38 OECD countries over the period 2000–2019. Column (1) presents the specification using the contemporaneous interaction term. The coefficient of $ISO14_{i,t} \times INT_{ij}$ is positive and statistically significant at the 1% level, indicating a positive estimated differential effect of exporter ISO 14001 certification intensity on international trade relative to intra-national trade.

Quantitatively, because $ISO14_{i,t}$ is the logarithm of the underlying certification-intensity index, the estimated coefficient has an elasticity interpretation. The coefficient of 0.051 implies that a 1% increase in certification intensity corresponds to approximately 0.051% higher international trade relative to intra-national trade. Based on the observed variation in the data, a one-standard-deviation increase in the log-transformed certification-intensity measure corresponds to approximately 6.34% higher international trade relative to intra-national trade (that is $[e^{0.051 \times 1.205} - 1] \times 100$).

Although Column (1) captures the contemporaneous differential effect of ISO 14001 certification intensity on international trade relative to intra-national trade, the effects of standardisation may unfold over time. Firms may require time to adopt environmental management practices, signal compliance to foreign partners, and adjust their international market relationships. To account for such delayed adjustment, Column (2) introduces the one-year lag of the ISO interaction term. The lagged specification also reduces reliance on contemporaneous co-movement between certification intensity and trade, while the source of identifying variation remains the international-versus-domestic comparison described in Section 3.

The estimated coefficient on the lagged interaction term remains positive and statistically significant, with a slightly larger magnitude of 0.054. This implies that a 1% increase in exporter certification intensity in the previous year is associated with

[12] Online Appendix S4 reports the sum of annual valid ISO 14001 certificate counts by country over 2000–2019.

[13] Table S3.1 shows that the ISO interaction coefficient is positive and statistically significant across all reported OLS and PPML specifications, although its magnitude varies with the estimator and FE structure.

Table 1
Baseline estimation results.

	(1)	(2)
$ISO14_{i,t} \times INT_{ij}$	0.051	
	(0.010)***	
$ISO14_{i,t-1} \times INT_{ij}$		0.054
		(0.010)***
N	28 880	27 436
Pseudo R^2	0.998	0.999
Exporter-year FEs	Yes	Yes
Importer-year FEs	Yes	Yes
Country-pair FEs	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variable is the interaction between exporter ISO 14001 certification intensity and the international-border indicator. Column (1) uses the contemporaneous interaction, while Column (2) uses its one-year lag. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

approximately 0.054% higher international trade relative to intra-national trade in the current year. Evaluated at a one-standard-deviation increase in the log-transformed certification-intensity measure, the corresponding increase in international trade relative to intra-national trade is approximately 6.72% (that is $[e^{0.054\times1.205} - 1] \times 100$).

The similarity between the contemporaneous and lagged estimates suggests that the baseline result is not driven solely by short-run fluctuations. Because the lagged specification allows for delayed adjustment while preserving the same international versus domestic identifying comparison, we use it as the preferred specification in the subsequent analysis.

To examine the dynamic pattern more broadly, Table A.1 in the Appendix reports additional lag specifications.[14] In the separate lag specifications, the coefficients on the first three lags remain positive and statistically significant, indicating that the positive estimated differential effect of ISO 14001 certification persists in the short run. The magnitude of the effect declines for longer horizons, and the coefficient becomes statistically insignificant by the fourth lag, suggesting that the effect weakens over time.

We also estimate a distributed-lag specification including lags one to four jointly. In this specification, the lagged ISO interaction terms are jointly significant, but the individual coefficients do not follow a monotonic pattern and the cumulative effect is not statistically significant. Overall, the dynamic evidence indicates that the positive estimated differential effect of ISO 14001 certification intensity is concentrated mainly in the short to medium term, while providing limited evidence of a persistent long-run cumulative effect.

5.2. Robustness checks

To assess the robustness of the baseline findings, we conduct a series of additional estimations addressing the measurement of ISO 14001 certification intensity, the FE structure, time-varying bilateral controls, crisis-related dynamics, persistence in trade relationships, and sample composition. Unless otherwise stated, all specifications retain the preferred one-year-lagged ISO interaction, the PPML estimator, exporter-year, importer-year, and country-pair FEs, and country-pair-clustered standard errors.

We first examine whether the results depend on the construction of ISO 14001 certification intensity. Table A.2 in the Appendix replaces the baseline measure with alternative normalisations and transformations. Online Appendix S5 documents the construction of these measures. In addition to the baseline logarithm of one plus certificates per million inhabitants, we normalise annual certificate counts by exporter GDP in 2000 and exporter output in 2000, use the untransformed number of certificates per million inhabitants, apply the inverse hyperbolic sine transformation, and construct a within-year fractional-rank measure.

Column (1) reproduces the baseline specification for comparison. Across Columns (2–5), when annual certification counts are normalised by initial GDP or initial output, entered as untransformed certificates per million inhabitants, or transformed using the inverse hyperbolic sine function, the estimated coefficient remains positive and statistically significant. Because the measures are expressed in different units and use different transformations, their coefficient magnitudes are not directly comparable. Nevertheless, the stability of the sign and statistical significance indicates that the baseline finding does not depend on the use of population as the denominator or on the particular logarithmic transformation.

[14] Egger et al. (2022) caution against the use of interval or time-averaged observations when studying dynamic trade effects and recommend consecutive annual data. Our dynamic specifications use consecutive annual observations throughout.

The coefficient obtained using the within-year fractional rank measure in Column (6) is also positive but statistically insignificant. Unlike the alternative cardinal measures, the fractional rank retains information only about an exporter's relative position in the annual certification distribution and discards information about absolute differences in certification intensity. Accordingly, the rank-based specification does not provide a statistically precise estimate of differential effect for changes in exporters' relative positions in the annual certification-intensity distribution. Overall, the evidence is stronger for the alternative cardinal measures than for the rank-based measure.

Online Appendix S6 reports an additional diagnostic test of exporter–importer certification complementarity. The coefficient on the interaction between exporter and importer certification intensities is positive but statistically insignificant, providing no evidence that the estimated differential effect becomes stronger when importer certification intensity is higher.

We next assess the sensitivity of the results to the FE structure. Online Appendix S3 shows that the ISO interaction coefficient remains positive across alternative estimator and FE specifications. Complementing those comparisons, Column (2) of Table A.3 in the Appendix adds border-year FEs to the preferred specification also reproduced in Column (1) for comparison. These FEs absorb year-specific shocks that affect all international trade flows relative to domestic trade flows. With their inclusion, the coefficient remains positive and broadly similar in magnitude, although it is estimated less precisely and is statistically significant at the 10% level. The baseline result is therefore not explained solely by common annual movements in international trade relative to intra-national trade.

We then augment the baseline specification by introducing an extended set of time-varying bilateral control variables, including RTAs, bilateral tariffs, several categories of economic sanctions, interstate soft conflicts, MIDs, and state policy measures. Due to differences in data availability, the model is estimated over alternative sample periods. For variables with full coverage, such as RTAs, tariffs, and economic sanctions, we use the full sample. For other controls, we restrict the sample to 2000–2018, 2000–2014, and 2008–2019 to incorporate interstate soft conflicts, MIDs, and state acts, respectively. In each case, we re-estimate the baseline specification while including the RTA indicator to ensure comparability across subsamples. Table 2 reports the results. Across all specifications, the coefficient on the ISO interaction term remains positive and statistically significant, indicating that the baseline findings are not driven by omitted policy or geopolitical factors.

Table A.4 in the Appendix provides a further assessment of these bilateral influences using two complementary approaches. First, we augment the baseline specification by including all economic sanctions imposed between country pairs within a given year. Second, we restrict the sample by excluding all country pairs that are affected by economic sanctions during the sample period. We repeat the same procedure for other control variables, including tariffs, interstate soft conflicts, MIDs, and state acts. The ISO coefficient remains positive and statistically significant in the tariff, sanctions, soft-conflict, and militarised-dispute exercises. The exclusion of pairs affected by state acts produces a much smaller sample and an imprecisely estimated coefficient in Column (10); this particular specification is therefore inconclusive rather than evidence against the baseline finding. Overall, the results are stable across the bilateral-factor checks for which sufficient identifying variation remains.

Given that the sample period includes the global financial crisis, we also assess whether the results are sensitive to crisis-related dynamics. We estimate the model separately for the pre-crisis (2000–2008) and post-crisis (2009–2019) periods and exclude the crisis years (2008–2010) from the full sample. The results, reported in Table A.5 in the Appendix, confirm that the positive estimated differential effect of ISO 14001 certification intensity on international trade relative to intra-national trade is not driven by crisis-related fluctuations.

Table A.6 in the Appendix addresses persistence in bilateral trade relationships by including lagged bilateral trade and, in a separate specification, its interaction with the ISO variable to examine whether the estimated differential effect of certification depends on lagged bilateral trade. The coefficient on the ISO interaction term remains positive and statistically significant across specifications, while the interaction with lagged trade is not statistically significant. This suggests that the estimated differential effect of ISO 14001 certification intensity does not depend systematically on prior bilateral trade conditions.

As a final step, we assess the sensitivity of the results to alternative sample definitions. To this end, we extend the sample to include all available 198 countries and re-estimate the baseline model. This allows us to assess whether the estimated relationship holds in a more heterogeneous global setting. In addition, we consider restricted samples focusing on EU-27 and EU-15 countries. These subsamples provide a more homogeneous institutional and economic environment and allow us to explore potential heterogeneity within Europe. The results, reported in Table A.7 in the Appendix, show that the estimated effect remains positive and statistically significant across samples. While the magnitude of the estimates varies, the overall pattern remains consistent with the baseline results, indicating that the estimates are not driven by sample selection and generalise to a broader set of economies.

Taken together, these robustness checks show that the positive estimated differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade is robust across alternative cardinal measures, FE specifications, bilateral controls, periods, and country samples. The rank-based and complementarity estimates are less precise and therefore do not support corresponding claims about relative certification positions or exporter–importer complementarity.

5.3. Sectoral heterogeneity

To examine whether the estimated differential effect of ISO 14001 certification intensity varies across industries, we extend the baseline specification to sector-level bilateral trade flows. Using data disaggregated into four broad sectors, agriculture,

Table 2
Robustness to time-varying bilateral controls.

	(1) RTAs	(2) Tariffs	(3) Sanctions	(4) RTAs	(5) SOFTconf	(6) RTAs	(7) MIDs	(8) RTAs	(9) State acts
		2000–2019		2000–2018		2000–2014		2008–2019	
$ISO14_{i,t-1} \times INT_{ij}$	0.051	0.042	0.043	0.064	0.057	0.045	0.034	0.017	0.014
	(0.010)***	(0.009)***	(0.009)***	(0.012)***	(0.012)***	(0.013)***	(0.013)***	(0.009)*	(0.008)*
$RTA_{ij,t}$	0.137	0.018	0.048	0.119	0.042	0.067	0.005	0.107	0.007
	(0.033)***	(0.036)	(0.039)	(0.033)***	(0.042)	(0.035)*	(0.043)	(0.029)***	(0.036)
$Tariff_{ij,t}$		−0.049	−0.049		−0.044		−0.039		−0.049
		(0.010)***	(0.010)***		(0.009)***		(0.009)***		(0.018)***
$ARMS_sanct_{ij,t}$			−0.640		−0.798		−0.916		−0.247
			(0.166)***		(0.170)***		(0.161)***		(0.089)***
$MILITARY_sanct_{ij,t}$			0.104		0.122		0.126		0.064
			(0.067)		(0.072)		(0.075)		(0.055)
$TRADE_sanct_{ij,t}$			0.411		0.458		0.646		−0.006
			(0.461)		(0.563)		(0.850)		(0.086)
$FINANCIAL_sanct_{ij,t}$			−0.553		−0.632		−0.745		−0.191
			(0.353)		(0.345)*		(0.324)**		(0.281)
$TRAVEL_sanct_{ij,t}$			0.822		0.452		0.000		0.560
			(0.376)**		(0.346)		(.)		(0.296)*
$SOFTconflict_{ij,t}$					−0.013		−0.017		0.003
					(0.007)*		(0.057)		(0.017)
$Display_of_Force_{ij,t}$							−0.114		−0.127
							(0.125)		(0.109)
$Use_of_Force_{ij,t}$							−0.067		0.349
							(0.122)		(0.466)
$Capital_controls_{ij,t}$									0.062
									(0.047)
$Exp_Imp_instruments_{ij,t}$									0.000
									(0.001)
$Foreign_invest_policy_{ij,t}$									−0.028
									(0.014)**
$Labor_migr_policy_{ij,t}$									−0.021
									(0.005)***
$Public_proc_policy_{ij,t}$									0.001
									(0.001)
$Subsidies_and_state_aid_{ij,t}$									0.000
									(0.000)
$Trade_defense_{ij,t}$									−0.019
									(0.010)*
$Non_tariff_barriers_{ij,t}$									−0.001
									(0.159)
N	27 436	27 436	27 436	25 992	25 992	20 216	20 216	17 328	17 328
Pseudo R^2	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Exporter-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variable is the one-year-lagged interaction between exporter ISO 14001 certification intensity and the international-border indicator. Specifications include additional time-varying bilateral controls and are estimated over different sample periods due to data availability. Columns (1–4–6–8) include the RTA indicator in the relevant sample periods. Column (2) includes tariffs. Column (3) includes different types of economic sanctions. Column (5) includes interstate soft conflicts. Column (7) includes different types of MIDs. Column (9) includes the different types of state acts. Variables lacking identifying variation are omitted. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 3
Estimation results at the sector level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Agriculture		Manufacturing		Mining & Energy		Services	
$ISO14_{i,t} \times INT_{ij}$	0.218		0.173		0.080		0.060	
	(0.030)***		(0.023)***		(0.065)		(0.018)***	
$ISO14_{i,t-1} \times INT_{ij}$		0.278		0.218		0.064		0.050
		(0.031)***		(0.021)***		(0.053)		(0.018)***
N	28 860	27 417	28 880	27 436	28 380	26 942	26 744	25 375
Pseudo R^2	0.993	0.994	0.996	0.996	0.994	0.995	0.999	0.999
Exporter-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on sector-level international trade relative to intra-national trade for 38 OECD countries over 2000–2019. The dependent variable is sector-level bilateral trade in levels, including domestic trade. The key explanatory variable is the interaction between exporter ISO 14001 certification intensity and the international-border indicator. Columns (1–2) cover agriculture. Columns (3–4) cover manufacturing. Columns (5–6) cover mining and energy. Columns (7–8) cover services. Odd-numbered columns use the contemporaneous interaction term, while even-numbered columns use its one-year lag. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

manufacturing, mining and energy, and services, we estimate the model separately for each sector.[15] Since ISO 14001 certification data are observed at the country-year level, the sectoral analysis does not measure sector-specific certification intensity; rather, it examines whether the estimated differential effect of exporter-level ISO 14001 certification intensity varies across sector-specific trade flows.

This disaggregation is also informative in light of Breinlich et al. (2024). They show that, in the leading case where trade-cost regressors do not vary across sectors, aggregate PPML estimates have a weighted-average interpretation in terms of heterogeneous sector-level parameters. Because ISO certification intensity is common across sectors within a country-year, separate sectoral estimates help reveal heterogeneity that may be hidden by the aggregate coefficient.

Table 3 reports the results. Across sectors, the coefficients on both the contemporaneous and lagged ISO interaction terms are positive, although their magnitude and statistical significance differ substantially, indicating pronounced heterogeneity in the estimated differential effect of ISO 14001 certification intensity.

In agriculture sector, a 1% increase in certification intensity corresponds to approximately 0.218% higher international trade relative to intra-national trade in the contemporaneous specification and 0.278% higher trade in the lagged specification. The larger lagged estimate indicates that the estimated differential effect is stronger in the subsequent period. This pattern is consistent with certification being particularly relevant for compliance and market-access conditions in agricultural trade.

For manufacturing, the corresponding estimates are 0.173% in the contemporaneous specification and 0.218% in the lagged specification. These results indicate a substantial positive estimated differential effect for manufacturing in both specifications. This is consistent with the role of certification in reducing information asymmetries, supporting quality assurance, and facilitating integration into global value chains, where compliance with internationally recognised standards is often required.

In contrast, the coefficients for mining and energy are not statistically significant in either the contemporaneous or lagged specifications. The estimates therefore provide no statistically precise evidence of a differential effect in mining and energy. A plausible explanation is that trade in mining and energy products is primarily driven by natural resource endowments, long-term supply contracts, and geopolitical considerations, which limit the relevance of voluntary environmental standards in shaping trade flows.

For services, a 1% increase in certification intensity corresponds to approximately 0.060% higher international trade relative to intra-national trade in the contemporaneous specification and 0.050% higher trade in the lagged specification. Although both estimates are statistically significant, their magnitude is smaller than in agriculture and manufacturing. This suggests that ISO 14001 certification may facilitate international transactions in services, but its role is more limited, likely reflecting the lower reliance on standardised production processes and certification-based market access compared to goods sectors.

We also assess whether the sectoral pattern is sensitive to the construction of certification intensity. Table A.8 reports the preferred lagged specification using the baseline measure, measures normalised by initial exporter GDP and initial exporter output,

[15] The structural gravity framework allows bilateral trade to be analysed at the sector or product level. The equation proposed by Anderson and Van Wincoop (2004) presents the well-known sectoral gravity model.

$$X^s_{ij,t} = \frac{Y^s_{i,t} E^s_{j,t}}{Y^s_w} \left(\frac{t^s_{ij,t}}{\Pi^s_{i,t} P^s_{j,t}} \right)^{1-\sigma_s} \tag{3}$$

Here, for a given set of country-level production $Y^s_{i,t}$ and expenditure $E^s_{j,t}$ values, s identifies a class of sector or product. Bilateral trade costs $t^s_{ij,t}$ and the corresponding multilateral resistance terms $Pi^s_{i,t}$ and $P^s_{j,t}$ are sector specific.

raw certificates per million inhabitants, and the inverse hyperbolic sine transformation, while keeping the OECD sample, PPML estimator, and FE structure unchanged. Construction details for these measures are provided in Online Appendix S5. Agriculture and manufacturing remain positive and statistically significant across all five measures; mining and energy remain statistically insignificant; and services remain positive and statistically significant, although smaller in magnitude. The qualitative sectoral pattern is therefore not specific to the baseline population scaling or logarithmic transformation. Because the alternative measures use different units and transformations, we do not compare coefficient magnitudes across specifications.

To assess external validity, we replicate the sectoral analysis using the global sample of 198 countries. The results, reported in Table A.9 in the Appendix, are broadly consistent with those obtained for the OECD sample. The coefficients for agriculture and manufacturing remain positive and statistically significant, while the estimates for mining and energy remain insignificant and those for services are weaker and less precisely estimated. While the magnitude of the estimates varies, the overall pattern remains consistent with the baseline results, indicating that they are not driven by sample selection and generalise to a broader set of economies.

Overall, the sectoral analysis documents substantial heterogeneity in the aggregate results. The positive estimated differential effect of ISO 14001 certification intensity is concentrated in sectors where compliance with international standards is more closely linked to production processes, quality assurance, and market access. This pattern is consistent with the relevance of these channels, but the aggregate country-year certification data do not allow us to identify the underlying mechanisms directly.

6. Conclusion

This study estimates the differential effect of exporter ISO 14001 certification intensity on international trade relative to intra-national trade within a structural-gravity framework. Using a balanced panel of 38 OECD countries over the period 2000–2019, three main findings emerge. First, the estimated differential effect is positive and statistically significant in the baseline OECD sample. Quantitatively, the coefficient of 0.051 implies that a 1% increase in the underlying certification-intensity index corresponds to approximately 0.051% higher international trade relative to intra-national trade in the contemporaneous specification. The corresponding coefficient in the one-year-lagged specification is slightly larger, at 0.054. Second, the positive estimate remains robust across alternative cardinal measures of certification intensity, FE structures, bilateral controls, crisis-period and trade-persistence checks, and alternative country samples. The rank-based and exporter–importer complementarity specifications yield less precise estimates for those distinct dimensions. Third, the analysis documents substantial sectoral heterogeneity and shows that the main differential-effect estimate is robust across alternative measures, specifications, and country samples. The estimated effect is particularly pronounced in agriculture and manufacturing, indicating that the trade relevance of ISO 14001 certification is not uniform across economic activities.

The positive estimated differential effect is consistent with mechanisms emphasised in the literature on standards and international trade. Internationally recognised certification may reduce information asymmetries by providing foreign buyers with a credible signal about suppliers' environmental management practices and by establishing shared expectations across trading partners (Potoski and Prakash, 2009; Clougherty and Grajek, 2014). This interpretation is also consistent with previous evidence linking ISO 14001 and other voluntary sustainability standards to export participation and export performance (Blyde, 2021; Sam and Song, 2022; Bemelmans et al., 2023). These mechanisms provide a plausible interpretation of the positive differential effect estimated for international relative to intra-national trade.

The sectoral analysis provides further evidence of heterogeneity in the estimated differential effect of ISO 14001 certification intensity across sectors. The largest estimated differential effects are found in agriculture and manufacturing, two sectors in which production processes, environmental practices, traceability, quality assurance, and participation in international supply chains are often closely interconnected. In these sectors, foreign buyers may attach particular importance to credible information about suppliers' EMSs. Certification may also facilitate access to supply chains in which lead firms seek to coordinate production and environmental practices across multiple countries and suppliers. In services, the estimated effect is smaller, reflecting both the heterogeneity of service activities and the less direct relevance of production-based EMSs for many service transactions. In mining and energy, the absence of a statistically significant effect may indicate that bilateral trade is more strongly shaped by natural resource endowments, geographical concentration, infrastructure, long-term supply contracts, and geopolitical considerations. In such circumstances, voluntary environmental certification may play a more limited role in determining trade patterns.

The results also have implications for policymakers, accreditation bodies, standard-setting organisations, and actors involved in international supply chains. The positive and robust estimated differential effect is consistent with credible environmental certification forming part of the institutional infrastructure supporting cross-border transactions. By improving the comparability and credibility of information about firms' environmental management practices, certification systems may complement more traditional trade-facilitation instruments focusing on tariffs, customs procedures, logistics, and regulatory cooperation. When considered alongside previous evidence on the unequal costs of compliance, our findings suggest that policies aimed at improving access to certification infrastructure and reducing unnecessary informational and administrative costs may help broaden participation, particularly among smaller firms and firms operating in environments with more limited technical capacity. Policy initiatives should therefore preserve the voluntary character of ISO 14001, promote credible and transparent certification procedures, and remain attentive to the possibility that private supply-chain requirements may exclude otherwise capable suppliers.

Several limitations should be acknowledged. First, the differential effect is identified from the international-versus-intra-national comparison within the structural-gravity specification, conditional on the included FEs. This identification operates under the maintained assumptions of the structural-gravity model rather than through externally assigned treatment variation. The estimated

Table A.1
Dynamic effects of ISO 14001 certification intensity.

	(1) Lag 1	(2) Lag 2	(3) Lag 3	(4) Lag 4	(5) Lags 1–4 jointly
$ISO14_{i,t-1} \times INT_{ij}$	0.054				−0.019
	(0.010)***				(0.011)*
$ISO14_{i,t-2} \times INT_{ij}$		0.055			0.097
		(0.012)***			(0.065)
$ISO14_{i,t-3} \times INT_{ij}$			0.032		0.061
			(0.013)**		(0.020)***
$ISO14_{i,t-4} \times INT_{ij}$				−0.010	−0.109
				(0.014)	(0.047)**
N	27 436	25 992	24 548	23 104	23 104
Pseudo R^2	0.999	0.999	0.999	0.999	0.999
Exporter-year FEs	Yes	Yes	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes	Yes	Yes
Joint test p-value					0.000
Cumulative effect					0.029
Cumulative p-value					0.189

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade using alternative lag specifications for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variables are interactions lagged by one to four years between exporter ISO 14001 certification intensity and the international-border indicator. Columns (1–4) report separate lag specifications. Column (5) reports a distributed-lag specification including all four lags jointly. The joint test reports the p-value for the null hypothesis that the four coefficients in Column (5) are jointly equal to zero. The cumulative effect is the sum of the four coefficients in Column (5), and the cumulative p-value refers to the null hypothesis that this sum is equal to zero. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

coefficient should therefore be interpreted as the differential effect within the structural-gravity model, under its maintained assumptions. Second, ISO 14001 certification is observed at the country-year level. The sectoral analysis therefore estimates the differential effect of aggregate exporter certification intensity on sector-specific international trade relative to intra-national trade, rather than the effect of sector-specific certification intensity. The available data also do not identify which firms are certified, whether certification is concentrated among exporters, or whether foreign buyers explicitly require ISO 14001 from their suppliers. The aggregate and sectoral results are consistent with signalling, coordination, and supply-chain mechanisms, but the available data do not permit these mechanisms to be tested directly at the firm level.

Future research could address these limitations by combining firm-level certification and trade data, mapping certificates to sectors and traded products, and examining whether the effect varies with firm size, productivity, export experience, or position within global value chains. It could also extend the aggregate exporter–importer complementarity analysis using more granular measures of certification diffusion in destination markets and examining the quality of national accreditation systems. Changes in certification costs, buyer requirements, environmental regulation, or access to accredited certification services may also provide useful settings for examining the underlying mechanisms more directly.

CRediT authorship contribution statement

Daniela Lena: Writing – original draft, Investigation, Conceptualization. **Tamar Taralashvili:** Writing – original draft, Investigation, Visualization, Methodology, Data curation.

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.

Appendix A

See Tables A.1–A.9.

Appendix B. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.inteco.2026.100757.

Table A.2
Alternative measures of ISO 14001 certification intensity.

	(1) Baseline	(2) GDP-scaled	(3) Output-scaled	(4) Certificates per million	(5) IHS	(6) Within-year rank
$ISO14_{i,t-1} \times INT_{ij}$	0.054					
	(0.010)***					
$ISO14^{GDP}_{i,t-1} \times INT_{ij}$		0.084				
		(0.013)***				
$ISO14^{Y}_{i,t-1} \times INT_{ij}$			0.087			
			(0.014)***			
$ISO14^{PM}_{i,t-1} \times INT_{ij}$				0.010		
				(0.000)***		
$ISO14^{IHS}_{i,t-1} \times INT_{ij}$					0.050	
					(0.009)***	
$ISO14^{Rank}_{i,t-1} \times INT_{ij}$						0.088
						(0.261)
N	27 436	27 436	27 436	27 436	27 436	27 436
Pseudo R^2	0.999	0.999	0.999	0.999	0.999	0.999
Exporter-year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade using alternative measures of certification intensity for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. In every column, the indicated ISO measure enters with a one-year lag and is interacted with the international-border indicator. Column (1) uses the baseline measure, defined as the logarithm of one plus the number of certificates per million inhabitants. Columns (2) and (3) use log-transformed certification counts normalised by exporter GDP in 2000 and exporter output in 2000, respectively. Column (4) uses the untransformed number of certificates per million inhabitants. Column (5) uses the inverse hyperbolic sine transformation of certificates per million inhabitants. Column (6) uses the within-year fractional rank of certificates per million inhabitants, constructed across all available exporters before the sample is restricted to OECD country pairs. Further construction details are provided in Online Appendix S5. Because the measures use different units and transformations, coefficient magnitudes are not directly comparable across columns. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A.3
Robustness to border-year FEs.

	(1) Baseline	(2) Border-year FEs
$ISO14_{i,t-1} \times INT_{ij}$	0.054	0.067
	(0.010)***	(0.037)*
N	27 436	27 436
Pseudo R^2	0.999	0.999
Exporter-year FEs	Yes	Yes
Importer-year FEs	Yes	Yes
Country-pair FEs	Yes	Yes
Border-year FEs	No	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variable is the one-year-lagged interaction between exporter ISO 14001 certification intensity and the international-border indicator. Column (1) reports the preferred baseline specification. Column (2) additionally includes border-year FEs, defined as interactions between the international-border indicator and year indicators. These FEs absorb common year-specific changes in international trade relative to intra-national trade. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A.4
Robustness to bilateral factors: inclusion and sample exclusions.

	(1) Includes	(2) Excludes	(3) Includes	(4) Excludes	(5) Includes	(6) Excludes	(7) Includes	(8) Excludes	(9) Includes	(10) Excludes
	All tariffs		All sanctions		All SOFTconflicts		All MIDs		All state acts	
$ISO14_{i,t-1} \times INT_{ij}$	0.042	0.048	0.059	0.064	0.054	0.055	0.055	0.053	0.077	0.009
	(0.010)***	(0.011)***	(0.009)***	(0.009)***	(0.010)***	(0.010)***	(0.010)***	(0.010)***	(0.011)***	(0.148)
$ALL_tariffs_{ij,t}$	−0.052									
	(0.009)***									
$ALL_sanctions_{ij,t}$			−0.013							
			(0.007)*							
$ALL_SOFTconflicts_{ij,t}$					−0.019					
					(0.009)*					
$ALL_MIDs_{ij,t}$							−0.148			
							(0.099)			
$ALL_state_acts_{ij,t}$									−0.002	
									(0.001)**	
N	27 436	4275	27 436	25 061	27 436	27 056	27 436	27 018	27 436	1292
Pseudo R^2	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Exporter-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variable is the one-year-lagged interaction between exporter ISO 14001 certification intensity and the international-border indicator. Columns (1-3-5-7-9) include all tariffs, economic sanctions, interstate soft conflicts, MIDs, and state acts between the two countries. Columns (2-4-6-8-10) restrict the sample by removing country pairs affected by the corresponding factors during the sample period. The number of observations therefore differs across the exclusion specifications. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A.5
Accounting for the global financial crisis.

	(1) 2000–2008	(2) 2009–2019	(3) Excludes 2008-9-10 years
$ISO14_{i,t-1} \times INT_{ij}$	0.137	0.038	0.062
	(0.021)***	(0.022)*	(0.010)***
N	11 552	15 884	23 104
Pseudo R^2	0.999	0.998	0.999
Exporter-year FEs	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variable is the one-year-lagged interaction between exporter ISO 14001 certification intensity and the international-border indicator. Column (1) uses the pre-crisis period (2000–2008). Column (2) uses the post-crisis period (2009–2019). Column (3) excludes the crisis and immediate recovery years (2008–2010) from the full sample. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A.6
Controlling for lagged bilateral trade.

	(1)	(2)
$ISO14_{i,t-1} \times INT_{ij}$	0.065	0.051
	(0.013)***	(0.022)**
$Trade_{ij,t-1}$	0.000	
	(0.000)	
$ISO14_{i,t-1} \times INT_{ij} \times Trade_{ij,t-1}$		0.000
		(0.000)
N	27 436	27 436
Pseudo R^2	0.999	0.999
Exporter-year FEs	Yes	Yes
Importer-year FEs	Yes	Yes
Country-pair FEs	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade for 38 OECD countries over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variable is the one-year-lagged interaction between exporter ISO 14001 certification intensity and the international-border indicator. Column (1) includes one-year-lagged bilateral trade as an additional control. Column (2) includes the interaction between one-year-lagged bilateral trade and the one-year-lagged ISO 14001 certification-intensity interaction. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A.7
Alternative country samples.

	(1) ALL-198	(2) EU-27	(3) EU-15
$ISO14_{i,t-1} \times INT_{ij}$	0.055	0.121	0.048
	(0.011)***	(0.014)***	(0.011)***
N	662 624	13 851	4275
Pseudo R^2	0.999	0.999	0.999
Exporter-year FEs	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on international trade relative to intra-national trade over 2000–2019. The dependent variable is bilateral trade in levels, including domestic trade. The key explanatory variable is the one-year-lagged interaction between exporter ISO 14001 certification intensity and the international-border indicator. Column (1) uses 198 countries. Column (2) restricts the sample to the EU-27 countries. Column (3) restricts the sample to the EU-15 countries. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A.8
Sector-level robustness to alternative measures of ISO 14001 certification intensity.

Sector	(1) Baseline	(2) GDP-scaled	(3) Output-scaled	(4) Raw per million	(5) IHS	*N*
Agriculture	0.278	0.419	0.433	0.003	0.259	27 417
	(0.031)***	(0.040)***	(0.044)***	(0.000)***	(0.030)***	
Manufacturing	0.218	0.340	0.368	0.002	0.202	27 436
	(0.021)***	(0.027)***	(0.029)***	(0.000)***	(0.020)***	
Mining & Energy	0.064	0.068	0.066	0.000	0.061	26 942
	(0.053)	(0.082)	(0.090)	(0.001)	(0.049)	
Services	0.050	0.065	0.060	0.001	0.046	25 375
	(0.018)***	(0.027)**	(0.030)**	(0.000)***	(0.017)***	
Exporter-year FEs	Yes	Yes	Yes	Yes	Yes	
Importer-year FEs	Yes	Yes	Yes	Yes	Yes	
Country-pair FEs	Yes	Yes	Yes	Yes	Yes	

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on sector-level international trade relative to intra-national trade using alternative measures of certification intensity for 38 OECD countries over 2000–2019. The dependent variable is sector-level bilateral trade in levels, including domestic trade. In every column, the indicated ISO measure enters with a one-year lag and is interacted with the international-border indicator. Column (1) uses the baseline measure, defined as the logarithm of one plus the number of certificates per million inhabitants. Columns (2) and (3) use log-transformed certification counts normalised by exporter GDP in 2000 and exporter output in 2000, respectively. Column (4) uses the untransformed number of certificates per million inhabitants. Column (5) uses the inverse hyperbolic sine transformation of certificates per million inhabitants. Further construction details are provided in Online Appendix S5. Because the measures use different units and transformations, coefficient magnitudes are not directly comparable across columns. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A.9
Sector-level estimates for 198 countries.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Agriculture		Manufacturing		Mining & Energy		Services	
$ISO14_{i,t} \times INT_{ij}$	0.319		0.171		−0.043		0.028	
	(0.028)***		(0.020)***		(0.049)		(0.015)*	
$ISO14_{i,t-1} \times INT_{ij}$		0.338		0.224		−0.059		0.008
		(0.030)***		(0.021)***		(0.048)		(0.016)
N	490 719	463 319	692 326	657 155	369 789	348 853	103 497	99 771
Pseudo R^2	0.993	0.994	0.996	0.996	0.994	0.995	0.999	0.999
Exporter-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table reports PPML estimates of the differential effect of exporter-specific ISO 14001 certification intensity on sector-level international trade relative to intra-national trade for 198 countries over 2000–2019. The dependent variable is sector-level bilateral trade in levels, including domestic trade. The key explanatory variable is the interaction between exporter ISO 14001 certification intensity and the international-border indicator. Columns (1–2) cover agriculture. Columns (3–4) cover manufacturing. Columns (5–6) cover mining and energy. Columns (7–8) cover services. Odd-numbered columns use the contemporaneous interaction term, while even-numbered columns use its one-year lag. All specifications include exporter-year, importer-year, and country-pair FEs. Standard errors are in parentheses, clustered at the country-pair level. * $p < .10$, ** $p < .05$, *** $p < .01$.

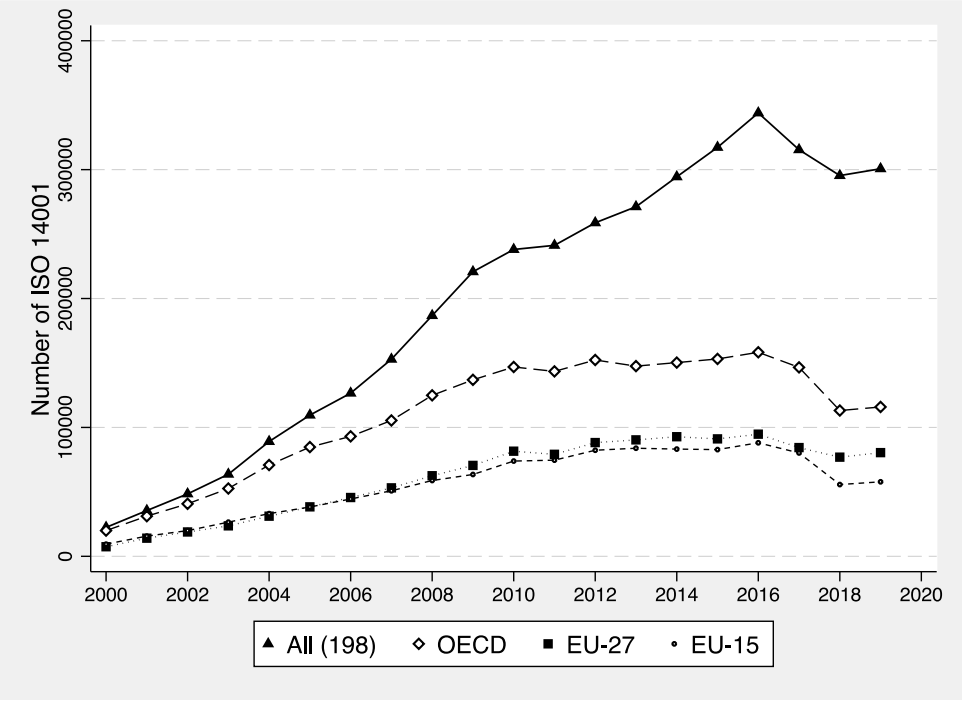


Fig. 1. ISO 14001 certificates across country groups.
Notes: This figure shows the total number of ISO 14001 certificates for all countries (198), 38 OECD countries, EU-27, and EU-15 over the period 2000–2019. The figure highlights the substantial share of certifications accounted for by 38 OECD countries.
Source: Authors' elaboration on the survey of the ISO compiled in 2022.

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