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International Standards, Product Substitutability, and Global Trade Network

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Abstract

This paper examines how internationally harmonised product standards shape trade partner selection by influencing product substitutability in global markets. Despite their central role in technical barriers to trade under the WTO/TBT Agreement, the economic effects of international standards remain underexplored, largely due to data limitations. To address this gap, we develop a comprehensive concordance between the International Classification for Standards (ICS) and HS 6-digit products, covering HS1988–HS2007. Using this concordance, we propose a product-type classification that distinguishes between homogeneous products, internationally standardised differentiated products, and non-standardised differentiated products.

We estimate an augmented gravity model using Poisson pseudo–maximum likelihood on bilateral trade flows among 57 countries. The results show a systematic ordering of distance elasticities across product types: homogeneous products exhibit the largest absolute distance elasticity, followed by internationally standardised differentiated products, while non-standardised differentiated products display the smallest elasticity. Interpreted in relative terms, these findings suggest that international standardisation is associated with higher product substitutability and a broader set of viable trade partners for differentiated goods.

Keywords: international trade; international standards; WTO/TBT; product-type classification; gravity model; PPML

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1 Introduction

Despite their central role in technical barriers to trade under the WTO/TBT Agreement, the economic effects of international standards on international trade remain underexplored. This paper examines how internationally harmonised product standards shape global trade patterns by influencing product substitutability and, consequently, the selection of trade partners. International standards are designed to ensure product compatibility, safety, and quality across countries. In an increasingly globalised production environment, where supply chains span multiple countries and regions, such standards can play a crucial role in reducing coordination costs and facilitating transactions across borders. By enhancing product comparability, international standards may increase the set of potential suppliers available to buyers and thereby intensify international competition.

The economic relevance of standardisation has increased alongside the deepening of global value chains. As production has become increasingly fragmented across countries, firms rely more heavily on imported intermediate inputs and face greater coordination costs across geographically dispersed production stages. Evidence from OECD input–output analyses shows that the import content of production and exports has risen substantially in advanced economies over the past two decades (Bo, Yamano, and Webb, 2010), highlighting the growing importance of standards in facilitating coordination and reducing transaction costs within global supply chains (Butter, Groot, and Lazrak, 2007). Empirical research on the trade effects of standardisation has been limited, largely due to data constraints. International standards are classified using the International Classification for Standards (ICS) [1], whereas trade data are organised according to product classifications such as the Harmonized System (HS). The absence of an official concordance between these classifications has hindered systematic empirical analysis at the product level. Existing studies therefore tend to rely on ad hoc concordances and focus on specific industries or regions. For example, the World Bank has developed partial concordances between EU standards and HS products using the Perinorm database for selected sectors such as textiles, clothing, footwear, and electronics (Shepherd, 2007; Czubala et al., 2007; Portugal-Perez et al., 2009; Reyes, 2011).

To address this limitation, this paper makes a data contribution by developing a comprehensive concordance between ICS categories and HS 6-digit products, covering HS1988–HS2007.

[1] From ISO website, one can download ICS codebook.

This concordance allows us to analyse the relationship between international standardisation and trade flows at a highly disaggregated product level across a broad set of countries and to distinguish systematically between internationally standardised and non-standardised products within narrowly defined product categories.

Standardisation can also affect international trade by increasing product compatibility and, in turn, the degree of substitutability across suppliers. Greater compatibility expands buyers' sets of potential suppliers, intensifies competition among producers, and facilitates adjustment within global value chains when supply disruptions occur. If internationally standardised products are more easily substituted across origins than non-standardised products, they should exhibit systematically different trade patterns. Motivated by this hypothesis, we develop a new product-type classification that categorises HS 6-digit products according to their degree of differentiation.

Building on this concordance, the paper makes two main contributions. First, we propose a novel product-type classification that builds on the product differentiation framework of Rauch (1999) by explicitly incorporating information on international standards. This extension allows us to distinguish between homogeneous products, internationally standardised differentiated products, and non-standardised differentiated products in a systematic manner. For expositional convenience, we refer to these three categories as O, S, and D products, respectively. Second, we quantify how differences in standardisation translate into differences in trade substitutability using an augmented gravity model estimated on bilateral trade flows among 57 countries.

Our empirical analysis focuses on how trade flows respond to distance and other trade frictions across product types. We interpret differences in estimated distance elasticities as reflecting variation in the degree of substitutability across products. The results show that homogeneous products exhibit the highest degree of substitutability, followed by internationally standardised products, while non-standardised differentiated products display the lowest substitutability.

These findings suggest that international standardisation reshapes global trade networks by expanding the set of viable trade partners for differentiated products. By increasing product substitutability, international standards can mitigate the rigidity of buyer–seller relationships and enhance the resilience of global value chains.

The remainder of the paper is structured as follows. Section 2 reviews the related literature on standards and international trade. Section 3 describes the construction of the ICS–HS concordance and presents descriptive evidence on standardisation patterns across industries. Section 4 outlines the empirical model and estimation strategy. Section 5 discusses the estimation results, and Section 6 concludes.

2 Related Literature

This paper relates to three strands of the literature: studies on standards and international trade, research on product differentiation and trade costs, and empirical work using gravity models to analyse trade patterns.

2.1 Standards and International Trade

A large body of research has examined the economic effects of standards, emphasising their role in shaping transaction costs, information frictions, and market access. Early theoretical contributions highlight that standards can reduce uncertainty about product quality, lower search costs, and facilitate transactions between buyers and sellers (Jones and Hudson, 1996; Blind, 2004). By narrowing quality dispersion and improving product comparability, standardisation can enhance market efficiency and intensify competition.

Empirical studies on standards and trade generally distinguish between national and international standards. National standards are often found to impede trade by acting as non-tariff barriers, whereas international standards tend to facilitate trade by harmonising technical requirements across countries (Swann, 2010a, 2010b). Using data from the Perinorm database, several studies document that international standards increase trade flows, particularly in manufacturing sectors, although the magnitude of these effects varies across industries and countries (Shepherd, 2007; Portugal-Perez et al., 2009; Reyes, 2011).

Despite these insights, empirical evidence remains fragmented. Most existing studies rely on partial or sector-specific concordances between standards classifications and trade data, limiting their ability to assess the effects of standardisation at a comprehensive and highly disaggregated product level. As a result, the implications of international standards for product substitutability and trade partner selection remain insufficiently explored.

Existing empirical studies on standards and trade are typically limited in terms of country coverage, sectoral scope, or data disaggregation. Much of the evidence focuses on individual importing countries, groups of advanced economies, or selected manufacturing sectors. In contrast, this paper examines the effects of international standards on trade flows across a broad set of countries using highly disaggregated HS 6-digit product-level data. For comprehensive reviews of the economics of standardisation[2], see Blind (2004) and Swann (2010a).

2.2 Product Differentiation, Substitutability, and Trade Costs

Our analysis also builds on the literature on product differentiation and trade costs. Rauch (1999) distinguishes between homogeneous products traded on organised exchanges and differentiated products, arguing that the latter are associated with higher search costs and rely more heavily on networks to facilitate trade. Subsequent studies have confirmed that trade costs, including distance and informational frictions, affect differentiated products more strongly than homogeneous goods.

While Rauch's classification has been widely used in empirical trade research, it treats product differentiation as a fixed technological characteristic and abstracts from institutional factors that may shape substitutability across suppliers. In contrast, international standards can directly influence the degree of compatibility among differentiated products by harmonising technical specifications across countries. This suggests that standardisation may systematically alter the degree of substitutability within categories traditionally classified as differentiated goods.

Recent work on global value chains further underscores this mechanism. As production processes become increasingly fragmented across borders, firms rely on standardised intermediate inputs to coordinate activities across geographically dispersed production stages (Butter, Groot, and Lazrak, 2007). In this context, standards may reduce coordination costs and increase the scope for supplier substitution, particularly in the presence of supply disruptions.

2.3 Contribution Relative to the Literature

This paper contributes to the existing literature by explicitly linking international standardisation to product substitutability in international trade. We extend the product-type classification of Rauch (1999) by incorporating information on international standards, allowing for a distinction between internationally standardised and non-standardised differentiated products. This extension provides a novel empirical framework to analyse how institutional features of products

[2]For example, Economies of Scale, Free rider problem, Network externalities, Bandwagon effects, Innovation and standards.

affect trade costs and partner selection.

Methodologically, our contribution complements the gravity-based literature following Anderson and van Wincoop (2003) by allowing the elasticity of trade with respect to distance to vary systematically across product types. By combining a comprehensive ICS–HS concordance with highly disaggregated HS 6-digit trade data across a broad set of countries, we provide new evidence on how international standards reshape trade patterns in a globalised economy.

3 Data and Construction of the ICS–HS Concordance

This section describes the construction of the dataset and the concordance between international standards and product-level trade data used in the empirical analysis. We first outline the data on international standards and trade flows and then explain how the ICS–HS concordance is constructed. Finally, we present descriptive evidence using figures and tables to illustrate patterns of standardisation across industries and over time.

3.1 Data Sources

International standards are primarily issued by three international standard-setting bodies: the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunication Union (ITU). Due to data availability, our analysis focuses on standards published by ISO and IEC, which together account for the majority of internationally harmonised product standards.

Figure 1 illustrates the annual number of international standards published from the first issuance in 1925 through 2010. The figure shows a marked acceleration in standard-setting activity from the mid-1990s onward. Table 1 reports the stock of published international standards by ICS 2-digit category, highlighting substantial heterogeneity in standardisation intensity across technical fields. These patterns are consistent with the increased emphasis on international harmonisation following the implementation of the WTO/TBT Agreement.

Bilateral trade data are obtained from the OECD BTDIxE database, which reports import values at the HS 6-digit level by exporter, importer, product, and year. The dataset covers trade flows among 57 countries and allows for a highly disaggregated analysis of international trade patterns across products and industries. The use of HS 6-digit data is essential for capturing variation in standardisation and substitutability within narrowly defined product categories.

Descriptive statistics for the estimation sample are reported in Appendix D.

3.2 Construction of the ICS-HS concordance

Because no official concordance exists between the International Classification for Standards (ICS) and product-level trade data, empirical analyses of standardisation necessarily rely on researcher-constructed mappings. Building on earlier work (Ijiri and Haneda, 2012), we construct a comprehensive concordance linking HS 6-digit products to ICS codes at the 5- and 7-digit levels[3]. The concordance is developed through a systematic comparison of textual product definitions in the HS and ICS classifications and covers all HS 6-digit products across HS revisions from HS1988 to HS2007. This coverage allows us to analyse the effects of international standardisation on trade flows at a highly disaggregated product level across countries.

Compared with existing concordances used in the literature–many of which are limited to selected industries, countries, or coarser product classifications–our mapping provides broad coverage and ensures consistency across HS revisions. As a result, it enables a unified analysis of standardisation and trade patterns across sectors and over time.

3.3 Measuring Standardisation and Product-Type Classification

Using the ICS–HS concordance, we assign international standards to HS 6-digit products and aggregate the associated standards at different levels of classification. We measure the degree of standardisation at the ISIC 2-digit industry level[4] by aggregating the number of international standards linked to HS 6-digit products within each industry. This measure serves as the basis for the industry-level descriptive statistics reported below.

Figures 2 and 3 show the import shares of internationally standardised products by ISIC 2-digit industry for 1995 and 2009, respectively. The figures indicate substantial cross-industry variation in the prevalence of standardised products, while within-industry patterns remain relatively stable over time. These observations suggest that industry-specific characteristics play an important role in shaping standardisation outcomes.

Figure 4 presents the average number of international standards per product by ISIC industry over the period 1988-2010. The figure highlights pronounced differences in standardisation

[3]For example, Economies of Scale, Free rider problem, Network externalities, Bandwagon effects, Innovation and standards.

[4]The definition of average numbers of standards publication in ISIC 2-digit category K is the following: The average standards publication in category K = the number of standards published in category K / the number of HS 6-digit products in category k.

intensity across industries, with relatively high levels observed in sectors traditionally characterised by low technological complexity or strong regulatory involvement. Figure 5 reports analogous patterns across end use categories, showing that household consumption goods tend to exhibit higher average levels of standardisation than intermediate or capital goods.

Based on the standardisation measures derived from the concordance, we classify HS 6-digit products into three mutually exclusive categories: homogeneous products traded on organised exchanges (O), internationally standardised differentiated products (S), and non-standardised differentiated products (D). This classification extends the framework of Rauch (1999) by allowing international standards to influence the degree of product differentiation and substitutability.

The classification enables a systematic comparison of trade patterns across products that differ not only in their technological characteristics but also in their degree of international harmonisation. In the following section, we use this classification to examine how standardisation affects trade costs and trade partner selection within an augmented gravity framework.

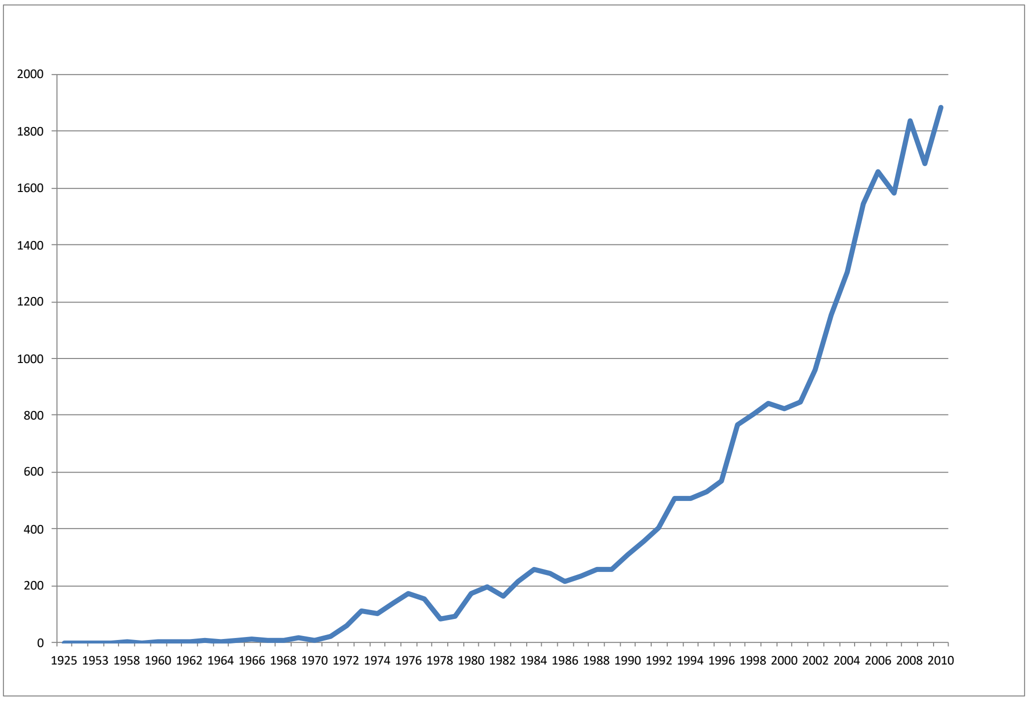

Figure 1: The Number of Published International Standards, 1925–2010

Source: Authors' calculation based on ISO standards data.

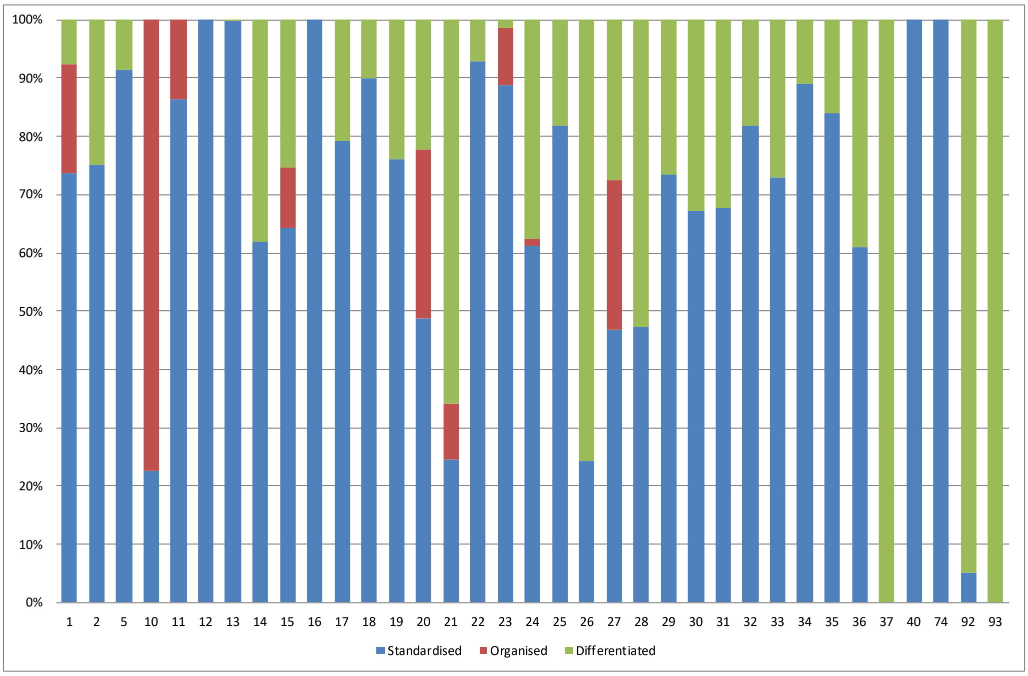

Figure 2: The Import Share of Standardised Products by ISIC 2-Digit Industry, 1995

Source: Authors' calculation based on BTDIxE and the ICS–HS concordance.

Table 1: The Stock of Published International Standards by ICS 2-Digit Category

Year \ ICS 2-digit category	01	03	07	11	13	17	19	21	23	25	27	29	31	33	35	37
1925-1989	285	11	6	29	79	124	30	52	87	182	33	169	137	144	134	68
1990	32	2	1	2	15	11	5	5	4	10	10	31	6	9	20	0
1991	19	3	1	10	13	16	4	6	13	20	6	22	22	23	37	2
1992	28	0	0	6	17	19	7	9	9	11	9	33	34	27	31	16
1993	36	4	0	17	22	28	3	11	8	53	5	31	21	29	48	13
1994	25	6	0	21	28	19	8	4	15	20	10	36	15	22	56	35
1995	26	3	1	14	25	30	7	20	13	14	10	34	19	39	80	4
1996	36	3	3	23	40	35	7	5	10	27	7	56	16	41	107	10
1997	37	3	2	25	37	42	7	29	40	17	16	75	25	55	56	19
1998	56	4	5	26	51	45	7	26	9	43	18	32	18	42	116	18
1999	54	8	4	24	60	22	6	32	23	81	10	61	22	54	103	8
2000	41	7	7	44	57	33	4	30	26	80	6	42	24	32	67	38
2001	47	14	7	34	68	44	16	23	22	62	6	68	33	73	54	22
2002	50	12	5	27	77	30	17	22	30	32	11	95	72	36	102	27
2003	33	21	18	42	81	34	20	16	23	79	8	107	72	88	86	17
2004	58	28	20	45	106	37	12	16	29	174	22	81	53	41	111	22
2005	55	35	16	63	92	47	6	15	46	162	33	125	52	93	166	31
2006	52	34	17	92	143	37	8	30	66	139	19	125	86	84	165	20
2007	52	38	13	75	130	47	19	28	79	113	35	144	53	72	175	21
2008	73	45	4	67	92	63	18	16	44	164	20	135	86	102	315	14
2009	67	60	9	100	91	55	7	27	57	54	29	155	53	146	248	23
2010	51	37	12	68	107	51	7	12	62	374	25	139	85	118	281	18
2011	41	29	9	64	65	29	6	44	40	66	17	123	60	66	187	12
SubTotal	1,254	410	160	918	1,496	898	231	478	755	1,977	365	1,919	1,064	1,436	2,745	458

Year	39	43	45	47	49	53	55	59	61	65	67	71	73	75	77	79	81	83	85	87	91	93	97	Total
1925-1989	4	86	10	91	99	86	21	107	16	75	167	255	82	37	231	57	29	63	18	42	65	0	31	3,242
1990	0	15	0	7	7	8	4	7	6	8	10	4	5	4	12	2	3	16	13	11	3	0	1	309
1991	2	17	0	3	3	4	9	6	2	13	14	4	17	4	19	1	2	10	2	0	3	0	4	356
1992	1	14	0	4	5	7	6	2	0	13	7	1	13	5	26	1	3	19	3	9	4	0	6	405
1993	1	14	0	3	10	6	9	34	0	13	17	6	1	16	13	1	1	18	1	5	5	0	5	508
1994	2	12	3	7	13	7	7	36	0	8	12	1	7	12	14	1	3	16	10	3	7	0	5	506
1995	3	8	0	5	6	9	7	33	0	11	18	4	2	10	12	2	1	33	5	3	16	0	3	530
1996	1	14	0	1	11	7	2	9	0	13	11	5	9	13	5	0	4	19	2	6	8	0	1	567
1997	3	18	0	7	15	11	7	16	0	20	26	19	7	29	19	1	4	38	6	12	10	0	15	768
1998	2	16	0	7	57	8	1	25	0	12	22	18	5	14	18	4	2	39	1	23	8	0	7	805
1999	1	22	1	9	13	4	3	28	0	16	17	21	7	23	20	2	2	56	5	10	5	1	3	841
2000	3	18	1	10	30	5	13	24	0	18	16	25	6	28	12	5	1	36	2	24	8	0	2	825
2001	1	51	0	13	3	7	3	17	12	12	15	11	7	23	10	3	4	38	8	4	11	0	3	849
2002	2	22	8	25	24	4	8	33	5	20	23	23	1	34	15	0	2	28	3	8	18	3	4	958
2003	4	35	4	19	25	14	6	21	13	14	21	30	5	32	21	12	15	68	2	15	13	1	18	1,153
2004	1	37	1	22	25	26	6	23	17	25	42	37	9	27	21	6	9	47	8	12	24	2	21	1,303
2005		44	1	15	21	23	23	35	3	19	31	29	4	20	45	3	15	62	20	9	43	5	36	1,543
2006	1	72	14	12	22	13	11	53	3	30	46	18	30	35	37	1	6	67	8	11	22	2	27	1,658
2007	1	34	6	24	26	21	15	24	7	20	23	15	22	32	23	5	15	69	12	28	32	0	34	1,582
2008	5	33	1	20	23	45	7	23	0	36	39	15	12	27	34	6	25	59	13	6	61	0	90	1,838
2009	2	44	7	22	13	20	13	51	1	33	46	25	12	36	27	5	7	48	9	11	39	2	33	1,687
2010	1	40	17	20	23	13	3	31	5	8	23	25	8	31	25	4	8	58	9	6	48	0	30	1,883
2011	3	30	4	9	26	6	4	19	3	14	18	8	1	26	46	5	14	29	9	10	34	2	28	1,206
SubTotal	44	696	78	355	500	354	188	657	93	451	664	599	272	518	705	127	175	936	169	268	487	18	407	25,325

Source: Authors' calculation based on ISO standards data.

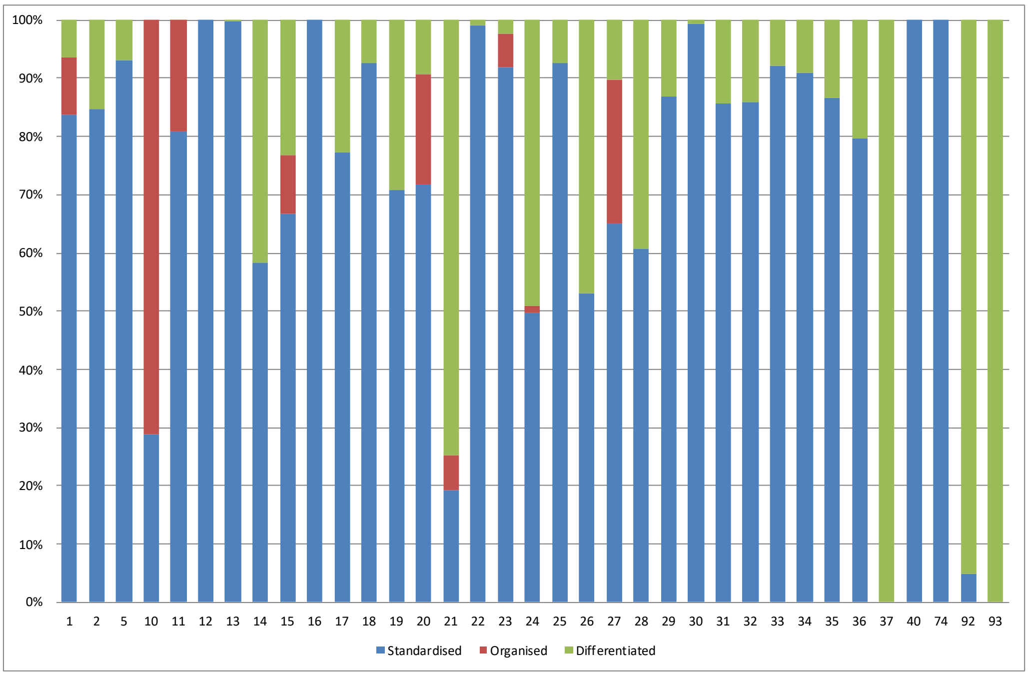

Figure 3: The Import Share of Standardised Products by ISIC 2-Digit Industry, 2009

Source: Authors' calculation based on BTDIxE and the ICS–HS concordance.

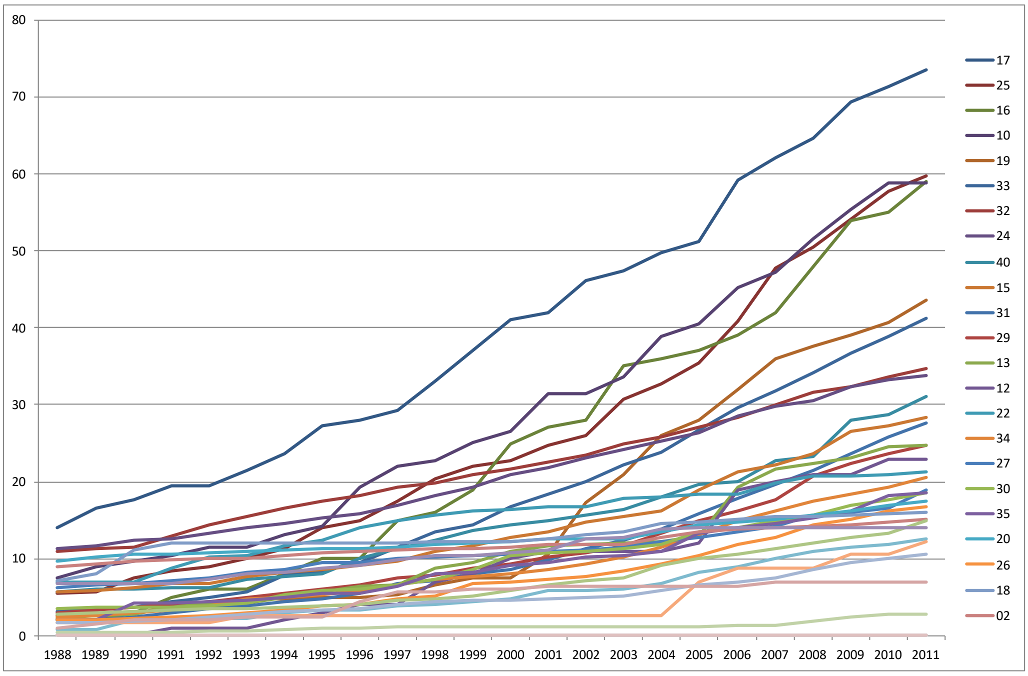

Figure 4: The Average Number of Published Standards by ISIC Industry, 1988–2010

Source: Authors' calculation based on ISO standards data and the ICS–HS concordance.

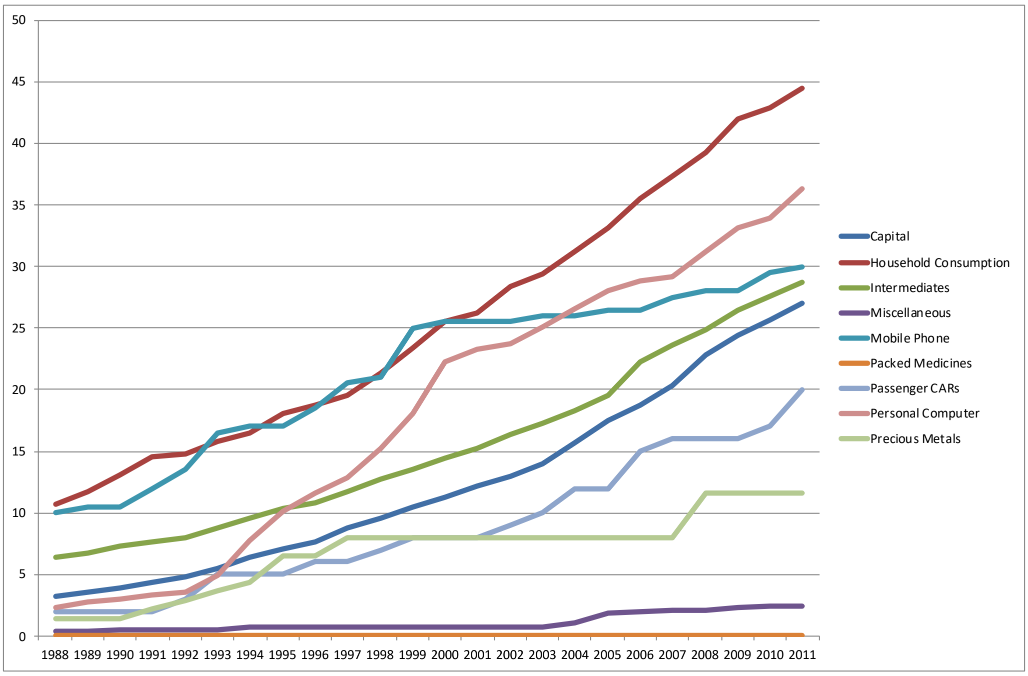

Figure 5: The Average Number of Published International Standards by End Use Category

Source: Authors' calculation based on BTDIxE and the ICS–HS concordance.

4 Empirical Model and Estimation Strategy

This section outlines the empirical framework used to examine how international standardisation affects trade patterns through changes in product substitutability. Following the recent gravity literature, we estimate the model using Poisson pseudo-maximum likelihood (PPML), which allows us to retain zero trade flows and yields consistent estimates in the presence of heteroskedasticity.

4.1 Model Specification

Our empirical analysis is based on a standard gravity model of international trade. Let X_{ijpt} denote imports of product p by country i from country j in year t. The baseline specification is given by:

$$\mathbb{E}[X_{ijpt} \mid \cdot] = \exp\big(\alpha + \beta_O(\ln Dist_{ij}) + Z'_{ij}\gamma + \mu_{ipt} + \nu_{jpt}\big)\,, \tag{1}$$

where $Dist_{ij}$ denotes bilateral distance, Z_{ij} is a vector of standard bilateral controls, including indicators for contiguity, common language, and colonial ties. The terms μ_{ipt} and ν_{jpt} denote importer-product-year and exporter-product-year fixed effects, respectively, which control for multilateral resistance terms and time-varying product-specific factors affecting trade.

This specification follows the structural gravity framework of Anderson and van Wincoop (2003) and its empirical implementation using PPML as proposed by Santos Silva and Tenreyro (2006).

To examine how standardisation affects product substitutability, we allow the responsiveness of trade flows to trade costs to vary across product types. As described in Section 3, products are classified into three mutually exclusive categories: homogeneous products traded on organised exchanges (O), internationally standardised differentiated products (S), and non-standardised differentiated products (D). We interpret differences in the estimated distance elasticity across these product types as reflecting differences in the degree of substitutability across suppliers. Products that are more easily substituted across origins are expected to exhibit a stronger negative response of trade flows to distance, reflecting more elastic trade patterns.

We implement this idea by interacting bilateral distance with product-type indicators. The estimating equation becomes:

$$\begin{aligned}\mathbb{E}[X_{ijpt} \mid \cdot] = \exp\Big(&\alpha + \beta_O(\ln Dist_{ij}\, O_p) \\ &+ \beta_S(\ln Dist_{ij}\, S_p) + \beta_D(\ln Dist_{ij}\, D_p) \\ &+ Z'_{ij}\gamma + \mu_{ipt} + \nu_{jpt}\Big)^5 \end{aligned} \tag{2}$$

where O_p, S_p, and D_p are indicator variables for the three product types. The coefficients β_O, β_S, and β_D capture the elasticity of trade with respect to distance for each product category.

Under the hypothesis that international standardisation increases product substitutability, we expect the absolute value of the distance elasticity to be larger for homogeneous products than for internationally standardised differentiated products, and larger for internationally standardised products than for non-standardised differentiated products, i.e.:

$$|\beta_O| > |\beta_S| > |\beta_D.| \tag{3}$$

[5] The model is estimated by Poisson pseudo-maximum likelihood (PPML), which specifies the conditional mean of trade flows. The multiplicative error term is implicit and is assumed to have unit conditional mean, so an explicit additive error term is not required.

4.2 Estimation and Identification

The model is estimated using PPML with high-dimensional fixed effects. This estimator naturally accommodates zero trade flows and is robust to different patterns of heteroskedasticity. Identification of the distance elasticities relies on cross-sectional variation in bilateral trade costs within narrowly defined product categories, conditional on importer-product-year and exporter-product-year fixed effects. Because the product-type classification is time invariant, the estimated coefficients capture systematic differences in trade cost sensitivity across product categories rather than short-run fluctuations in trade flows.

Within this framework, distance serves as a summary measure of trade costs, encompassing transportation costs, information frictions, and other barriers correlated with geographic separation. Larger (in absolute value) distance elasticities indicate a higher degree of substitutability across suppliers. Accordingly, differences in estimated elasticities across O, S, and D products provide evidence on whether international standardisation enhances product compatibility and expands the set of viable trade partners.

5 Results

This section presents the empirical results from the augmented gravity model introduced in Section 4. We estimate the model using the Poisson pseudo-maximum likelihood (PPML) estimator, which allows us to retain zero trade flows and obtain consistent estimates in the presence of heteroskedasticity. Our primary interest lies in comparing the estimated distance elasticities across product types in order to assess how international standardisation shapes product substitutability and trade partner selection.

Specifically, we focus on the coefficients on distance interacted with the product-type indicators for homogeneous products (O), internationally standardised differentiated products (S), and non-standardised differentiated products (D). Differences in these coefficients capture variation in the sensitivity of trade flows to geographic trade frictions across product categories. Following the interpretation discussed in Section 4, smaller absolute distance elasticities are taken to indicate a higher degree of substitutability across suppliers.

We begin by reporting baseline estimation results and testing whether the distance elasticities differ systematically across product types. We then conduct pairwise comparisons to evaluate the statistical significance of these differences. Finally, we examine the robustness of our findings to alternative specifications and sets of controls.

5.1 Baseline Results

Table 2 reports the PPML estimates of distance elasticities by product type. Panel A presents the estimated coefficients on distance interacted with the indicators for homogeneous products (O), internationally standardised differentiated products (S), and non-standardised differentiated products (D) across alternative specifications. Across all specifications, the estimated distance elasticity is largest in absolute value for homogeneous products, followed by internationally standardised differentiated products, and smallest for non-standardised differentiated products. This ordering is stable across specifications that include different sets of controls and fixed effects.

The estimated coefficients imply that trade in homogeneous products is most sensitive to geographic trade frictions, whereas trade in non-standardised differentiated products is least sensitive. Internationally standardised differentiated products occupy an intermediate position. These results are consistent with the hypothesis that international standardisation is associated with greater product substitutability relative to non-standardised differentiated goods, while still exhibiting lower substitutability than homogeneous products.

Panel B of Table 2 reports pairwise tests of equality of distance elasticities across product types. The results show that the differences in distance elasticities between all pairs of product types–O versus S, S versus D, and O versus D–are statistically significant. These findings confirm that the observed ordering in distance elasticities reflects systematic and statistically meaningful differences across product categories rather than sampling variation.

Taken together, the results in Table 2 provide robust evidence that international standardisation is associated with a distinct pattern of trade cost sensitivity. While distance captures a broad set of trade frictions, the relative differences in estimated distance elasticities across product types offer informative evidence on variation in product substitutability and trade partner selection in international markets.

5.2 Robustness and Economic Interpretation

We assess the robustness of the baseline findings by estimating alternative versions of the gravity model. A key dimension concerns the treatment of multilateral resistance and other country-specific trade frictions that are correlated with bilateral distance. In Models (1)-(3), which include the full set of high-dimensional fixed effects discussed in Section 4 and thereby absorb multilateral resistance terms in the sense of Anderson and van Wincoop (2003), the estimated distance elasticities display a stable and economically meaningful ordering across product types: homogeneous products (O) are most sensitive to distance, followed by internationally standardised differentiated products (S), while non-standardised differentiated products (D) are least sensitive.

By contrast, in Models (4) and (5), which exclude fixed effects that absorb multilateral resistance, the ordering of distance elasticities becomes unstable and reverses in some specifications. This pattern is consistent with the well-established result that failing to control for multilateral resistance leads to biased estimates of bilateral trade frictions. As emphasised by Anderson and van Wincoop (2003), multilateral resistance terms are an integral component of gravity models, and their omission distorts the interpretation of distance coefficients. Subsequent contributions have repeatedly stressed this point, warning that estimates obtained without controlling for multilateral resistance can be severely misleading (Baldwin, 2006; Head and Mayer, 2014). Accordingly, we treat Models (1)-(3) as our preferred specifications and focus the discussion on those estimates.

Additional robustness checks are reported in Appendix C. The qualitative ordering of distance elasticities across product types is preserved when alternative estimation methods, distance measures, sample restrictions, and definitions of product types are employed.

5.3 Discussion of Results

The empirical results indicate that trade cost sensitivity varies systematically across product types. In particular, homogeneous products exhibit the largest absolute distance elasticity, followed by internationally standardised differentiated products, while non-standardised differentiated products display the smallest elasticity. This ordering is consistent with differences in the degree of product substitutability across suppliers.

Within the gravity framework, distance serves as a proxy for a broad set of trade frictions, including transportation costs, information frictions, and coordination costs associated with geographically dispersed production networks. A larger absolute distance elasticity implies that trade flows are more responsive to changes in such frictions. Interpreted in relative terms, this suggests that buyers can more readily switch between alternative suppliers when trade costs change.

Against this background, the intermediate position of internationally standardised differentiated products is particularly informative. Compared with non-standardised differentiated products, internationally standardised products exhibit greater sensitivity to trade costs, consistent with reduced buyer–supplier specificity and enhanced compatibility across suppliers. At the same time, their distance elasticity remains smaller in absolute value than that of homogeneous products traded on organised exchanges, indicating that international standardisation does not fully eliminate product differentiation. These findings highlight the role of international standardisation as an institutional mechanism that reshapes, rather than homogenises, global trade patterns. By increasing product compatibility, standards appear to expand the set of viable trade partners for differentiated products, while preserving scope for differentiation based on quality, branding, or other product attributes. In this sense, standardisation alters the margins along which firms compete without collapsing differentiated products into homogeneous goods.

The discussion in this section focuses on reduced-form evidence on substitutability inferred from relative differences in distance elasticities. A fuller assessment of the broader economic and policy implications of international standardisation–particularly for the organisation and resilience of global value chains– is taken up in the following section.

6 Discussion and Conclusion

This paper has examined how international standardisation shapes global trade patterns by influencing product substitutability and, in turn, trade partner selection. Using a newly constructed concordance between international standards classified under the International Classification for Standards (ICS) and HS 6-digit trade data, we proposed a product-type classification that distinguishes between homogeneous products, internationally standardised differentiated products, and non-standardised differentiated products. Estimating an augmented gravity model with appropriate controls for multilateral resistance, we provided systematic evidence on differences in trade cost sensitivity across these product types.

The central empirical finding is a clear and robust ordering of distance elasticities. Homogeneous products exhibit the largest absolute distance elasticity, followed by internationally standardised differentiated products, while non-standardised differentiated products display the smallest elasticity. This ordering is stable in specifications that appropriately control for multilateral resistance and becomes unstable when such controls are omitted, underscoring the

Table 2: Distance Elasticities by Product Type

	PPML with Year / Importer / Exporter Fixed Effects				
	(1)	(2)	(3)	(4)	(5)
Panel A: PPML Estimates					
Distance elasticity (D)	-0.750^{**}	-0.930^{**}	-0.930^{**}	-0.529^{**}	-0.529^{**}
	(0.027)	(0.028)	(0.028)	(0.073)	(0.073)
Distance elasticity (S)	-0.805^{**}	-0.980^{**}	-0.980^{**}	-0.479^{**}	-0.479^{**}
	(0.025)	(0.027)	(0.027)	(0.073)	(0.073)
Distance elasticity (O)	-1.393^{**}	-1.589^{**}	-1.589^{**}	-0.316^{**}	-0.316^{**}
	(0.056)	(0.059)	(0.059)	(0.064)	(0.064)
Contiguous	0.654^{**}				
	(0.083)				
Common official language	0.078				
	(0.081)				
Colony	0.024				
	(0.083)				
Observations	20,977,473	20,977,473	20,977,473	27,591,648	27,591,648
FE: Year	Yes	Yes	No	Yes	No
FE: MRT, Importer	Yes	Yes	Yes	No	No
FE: MRT, Exporter	Yes	Yes	Yes	No	No
Panel B: Pairwise Tests of Differences in Distance Elasticities					
	D – S		D – O		S – O
Coefficient	0.0544		0.6423		0.5878
Standard error	(0.0138)		(0.0563)		(0.0549)
p-value	0.0001		0.0000		0.0000

Notes: This table reports Poisson pseudo-maximum likelihood (PPML) estimates of distance elasticities by product type. Panel A reports coefficients on bilateral distance interacted with indicators for homogeneous products traded on organised exchanges (O), internationally standardised differentiated products (S), and non-standardised differentiated products (D). Contiguity, common official language, and colonial ties are included as bilateral controls, where identified. Models (1)–(3) include importer–product–year and exporter–product–year fixed effects, which absorb multilateral resistance terms in the sense of Anderson and van Wincoop (2003). Models (4)–(5) exclude these fixed effects and are reported for comparison. Panel B reports pairwise tests of equality of distance elasticities based on linear combinations of the PPML estimates from Model (1). Robust standard errors are reported in parentheses. * and ** denote significance at the 10 and 5 percent levels, respectively. Additional robustness checks using alternative estimators that explicitly account for zero trade flows, including Heckman selection models, are reported in Appendix C.

importance of accounting for multilateral resistance in gravity estimations. Interpreted in relative terms, these results point to meaningful variation in the degree of substitutability across product types.

The intermediate position of internationally standardised differentiated products sheds light on the economic role of standardisation. International standards appear to increase product compatibility and reduce buyer–supplier specificity relative to non-standardised differentiated goods, thereby expanding the set of potential trading partners. At the same time, standardisation does not eliminate differentiation entirely: standardised products remain less substitutable than homogeneous products traded on organised exchanges. In this sense, international standardisation reshapes the structure of competition without collapsing differentiated products into homogeneous ones.

These findings have implications for the organisation of global value chains. By facilitating substitution across suppliers located in different countries, international standards may ease adjustment to shocks that disrupt production in specific regions and contribute to greater resilience in global supply chains. From a policy perspective, the results underscore the dual role of international standardisation: while standards may impose compliance costs, their harmonisation across countries can also facilitate participation in international markets by reducing coordination costs and broadening buyers' sets of feasible suppliers.

Several limitations suggest directions for future research. First, the analysis relies on reduced-form evidence inferred from relative differences in distance elasticities rather than on direct estimation of structural substitution elasticities. Second, while the ICS–HS concordance enables a comprehensive product-level analysis, it does not capture variation in the stringency or enforcement of standards across countries. Incorporating such dimensions or extending the analysis to firm-level data would provide further insight into the mechanisms through which standardisation affects trade.

In conclusion, this paper contributes to the literature on standards and international trade by providing new product-level evidence on how international standardisation reshapes trade partner selection through its effect on product substitutability. By combining a novel data construction with a gravity-based empirical framework, the analysis highlights the systematic role of international standards in structuring global trade networks, with implications for competition, global value chains, and trade policy.

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Appendix

A Variable Definitions

Table A1 provides definitions of all variables used in the empirical analysis.

Table A.1: Variable Definitions

Variable	Definition	Source
X_{ijpt}	Import value of HS 6-digit product p imported by country i from country j in year t (zeros included).	OECD BTDIxE
$Dist_{ij}$	Great-circle distance between the largest cities of countries i and j.	CEPII
Common language	Dummy =1 if countries share a common language.	CEPII
Contiguity	Dummy =1 if countries share a land border.	CEPII
Colonial ties	Dummy =1 if countries had a colonial relationship.	CEPII
O_p	Homogeneous products traded on organised exchanges.	ICS–HS concordance
S_p	Internationally standardised differentiated products.	ICS–HS concordance
D_p	Non-standardised differentiated products.	ICS–HS concordance
μ_{ipt}	Importer–product–year fixed effects.	—
ν_{jpt}	Exporter–product–year fixed effects.	—

B Construction of the ICS–HS Concordance

This appendix describes in detail the procedure used to construct the concordance between the International Classification for Standards (ICS) and HS 6-digit product codes.

B.1 Motivation

There is no official concordance linking the International Classification for Standards (ICS) to product-level trade classifications such as the Harmonized System (HS). As a result, empirical analyses of the effects of standardisation on international trade must rely on researcher-constructed mappings. To address this limitation, we develop a comprehensive concordance between HS 6-digit products and ICS codes, building on the approach documented in Ijiri and Haneda (2012).

B.2 Classification Systems

B.2.1 Harmonized System (HS)

The Harmonized System is an internationally standardised product classification used to record trade flows. Our analysis uses HS 6-digit codes, which provide the highest level of internationally comparable product detail. To ensure consistency over time, the concordance covers all HS revisions from HS1988 to HS2007.

B.2.2 International Classification for Standards (ICS)

ICS is a hierarchical classification system used to organise international standards according to their technical content. ICS codes are structured at different levels of aggregation, with 2-digit codes indicating broad technical fields and 5- and 7-digit codes capturing more detailed technological specifications. Our concordance uses ICS codes at the 5- and 7-digit levels to ensure a precise mapping between standards and products.

B.2.3 Mapping Procedure

The concordance is constructed through a systematic comparison of textual definitions in the HS and ICS classification manuals. For each HS 6-digit product, we examine the official product descriptions and identify ICS codes whose scope corresponds to the technical characteristics and intended use of the product. The mapping procedure follows three guiding principles: 1. Conceptual Consistency: An ICS code is linked to an HS product only if the technical content of the standard is directly relevant to the physical characteristics, functionality, or performance requirements of the product. 2. Inclusiveness: When multiple ICS codes apply to a given HS product, all relevant codes are retained to capture the full range of standards potentially affecting the product. 3. Stability across HS Revisions: The mapping is constructed to remain consistent across HS revisions from HS1988 to HS2007, with adjustments made only to preserve conceptual equivalence.

B.2.4 Aggregation of Standards

Using the ICS–HS concordance, international standards published by ISO and IEC are assigned to HS 6-digit products. For each product, we count the number of standards associated with the corresponding ICS codes. These product-level standard counts are then aggregated to higher levels of classification, such as ISIC 2-digit industries and end use categories, as described in Section 3.

B.2.5 Validation and Limitations

To assess the robustness of the concordance, we compare the implied distribution of standards across industries with qualitative evidence on standardisation intensity from industry reports. While the concordance necessarily involves judgement in the interpretation of textual definitions, its comprehensive coverage of all HS 6-digit products and consistency across HS revisions represent a substantial improvement over existing mappings used in the literature. The concordance does not capture variation in the economic importance or enforcement of individual standards, nor does it distinguish between mandatory and voluntary standards. These limitations should be borne in mind when interpreting the empirical results.

C Robustness Checks

This appendix reports robustness checks that complement the baseline results presented in Section 5. The purpose of these exercises is to examine whether the main findings–namely, the systematic ordering of distance elasticities across product types–are sensitive to alternative treatments of multilateral resistance, estimation methods, and sample selection.

C.1 Alternative Treatments of Multilateral Resistance and Estimation Methods

Table C1 reports estimation results for the year 2000 using alternative gravity specifications based on Heckman selection and Poisson pseudo-maximum likelihood (PPML) estimators. In contrast to the baseline specifications in Table 2, which absorb multilateral resistance terms through high-dimensional fixed effects, the specifications reported in Table C1 proxy multilateral resistance using remoteness variables following Carrère (2006). Distance is measured consistently as great-circle distance, identical to the definition used in the main analysis. In addition, Table C1 estimates the gravity model separately for each product type–homogeneous products (O), internationally standardised differentiated products (S), and non-standardised differentiated products (D)–rather than relying on interaction terms within a pooled specification. This approach allows us to assess whether the relative magnitude of distance elasticities across product types is sensitive to sample selection and estimation strategy. Across both Heckman and PPML estimation results, the estimated coefficients on distance display a consistent ordering across product types. Homogeneous products exhibit the largest absolute distance elasticity, followed by internationally standardised differentiated products, while non-standardised differentiated products display the smallest elasticity. This pattern mirrors the baseline findings reported in Table 2. The coefficients on economic mass variables and other gravity controls generally display the expected signs and statistical significance across specifications. While the estimated effects of gravity dummy variables differ somewhat across estimation methods, these differences do not alter the relative ordering of distance elasticities across product types. Taken together, the results in Table C1 confirm that the central empirical findings are robust to alternative treatments of multilateral resistance, estimation methods, and product-type–specific sample selection.

D Descriptive Statistics

This appendix reports descriptive statistics for the estimation sample described in Sections 3 and 4. Trade values are measured at the HS 6-digit product level and are expressed in nominal US dollars. Distance is measured as the great-circle distance between major cities of trading partners. Panel A of Table D1 reports summary statistics for the full estimation sample, while Panel B reports statistics for the subsample of strictly positive trade flows. Table D2 presents descriptive statistics by product type, distinguishing homogeneous products traded on organised exchanges (O), internationally standardised differentiated products (S), and non-standardised differentiated products (D). The sample consists of bilateral trade flows among 57 countries in 2000 and 2005.

Table C.1: Robustness Checks Using Alternative Estimation Methods

Year:2000	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Product-type	ALL	O	S	D	O	S	D
Estimation method	Heckman	Heckman	Heckman	Heckman	PPML	PPML	PPML
	LnImport	LnImport	LnImport	LnImport	Import	Import	Import
GDP_i	0.773***	1.074***	0.776***	0.758***	0.851***	0.783***	0.770***
	(241.90)	(19.76)	(202.26)	(132.74)	(12.98)	(3614.12)	(51.48)
GDP_j	0.989***	1.145***	0.995***	0.970***	0.460***	0.764***	0.791***
	(149.41)	(11.86)	(124.92)	(82.15)	(19.42)	(3525.35)	(87.79)
Distance	-1.050***	-1.697***	-1.055***	-1.016***	-0.798***	-0.631***	-0.587***
	(-156.39)	(-13.91)	(-129.57)	(-87.11)	(-11.75)	(-1565.14)	(-31.40)
Remoteness_i	0.525***	0.490***	0.516***	0.535***	1.112***	0.591***	0.618***
	(74.94)	(4.84)	(61.87)	(41.55)	(5.13)	(371.75)	(9.75)
Remoteness_j	0.423***	1.282***	0.511***	0.173***	2.035***	1.014***	0.206***
	(56.28)	(13.76)	(57.00)	(12.42)	(6.70)	(645.34)	(3.48)
Contig	0.590***	1.563***	0.586***	0.575***	0.674***	0.596***	0.676***
	(78.56)	(12.05)	(65.21)	(42.12)	(5.05)	(525.59)	(14.03)
Comlang_ethn	0.484***	0.823***	0.460***	0.537***	0.216	0.326***	0.336***
	(70.79)	(7.79)	(56.59)	(42.67)	(1.36)	(384.84)	(8.81)
Colony	0.264***	-0.0313	0.258***	0.285***	-0.615***	-0.159***	-0.00203
	(32.37)	(-0.27)	(26.51)	(19.06)	(-3.36)	(-125.42)	(-0.04)
_cons	-19.70***	-32.14***	-20.15***	-18.17***	-12.14***	-15.49***	-13.81***
	(-83.34)	(-8.99)	(-70.99)	(-43.01)	(-4.58)	(-1377.09)	(-23.47)
mills	1.840***	4.266***	1.865***	1.717***			
lambda	(73.88)	(11.16)	(61.77)	(39.51)			
Sample	13,795,824	169,176	9,824,976	3,801,672	169,176	9,824,976	3,801,672

t statistics
* p<0.05, ** p<0.05, *** p<0.001

Table D.1: Descriptive Statistics

	Obs.	Mean	Std. Dev.	Min	Max
Panel A: Full Sample					
Import value (USD)	28,084,356	8.18×10^{11}	6.46×10^{13}	0	1.90×10^{17}
Distance (km)	28,084,356	6,843	4,884	60	19,586
Zero trade flow (share)	28,084,356	0.769	0.422	0	28,084,356
Panel B: Non-Zero Trade Sample					
Import value (USD)	6,489,392	3.54×10^{12}	1.34×10^{14}	5,000	1.90×10^{17}
Distance (km)	6,489,392	5,439	4,703	60	19,586

Notes: See Appendix D for details on variable definitions and data sources. Panel A reports descriptive statistics for the full estimation sample. Panel B reports descriptive statistics conditional on strictly positive trade flows.

Table D.2: Descriptive Statistics by Product Type

	Mean value	Zero share	Mean dist.	HS6 prod.	Observations
O	3.51×10^{12}	0.852	4,632	54	344,394
S	8.70×10^{11}	0.771	5,427	3,472	20,000,844
D	5.62×10^{11}	0.760	5,490	1,587	7,739,118

Notes: Mean value denotes mean trade value in U.S. dollars. Zero share denotes the share of zero trade flows. Mean dist. denotes average bilateral distance in kilometres. HS6 prod. denotes the number of HS 6-digit products. O, S, and D denote homogeneous products traded on organised exchanges, internationally standardised differentiated products, and non-standardised differentiated products, respectively.