No double standards: quantifying the impact of standard harmonization on trade

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Abstract

This paper highlights a novel channel that contributes to higher trade integration: the release of harmonized, voluntary product standards. Standards define product characteristics that ensure compatibility, quality and consistency. Harmonized standards unify these characteristics across countries and reduce country-specific adaption costs. We create a novel database on cross-country standards and show that harmonized standards have contributed up to 12% to the growth in trade. We build a heterogeneous firm model where harmonized standards generate scale effects and induce firms to adopt the standard. They benefit from higher demand, charge higher prices and sell larger volumes. Firm-level evidence supports these predictions.

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1 Introduction

Product standards are omnipresent and affect production processes in virtually all industries (ISO, 2016). Prominent examples are A4 paper format, electricity plugs or 4G mobile phone standards. Over the last decades, the bulk of standard development is led by international standard-setting organizations (SSOs), resulting in an increasing number of standards being harmonized across countries. This silent form of trade integration, which is not necessarily the result of government trade policy, shapes the way firms produce and sell their output abroad.

Standards are developed by standard-setting organizations (SSOs), where industry experts work together to agree on the formal specification of product characteristics. Standards are voluntary and adopters can choose to use them in their production processes. The benefits of standards have already been pointed out as early as Kindleberger (1983). Through standardization, firms are able to overcome information asymmetries (Leland, 1979), to ensure interoperability and to take advantage of positive network effects (Katz and Shapiro, 1985; Farrell and Saloner, 1985). For example, quality and technical standards enable consumers to better assess product attributes through certification or labeling. Compatibility standards (think of screw threads or mobile phone standards) allow for network effects and economies of scale, thus facilitating supply chains and mass production.

The compliance with standards requires investment costs. When adapting products and processes to a specific standard, producers have to design standard-compatible blueprints, retool machines and potentially reorganize plants. Harmonized standard releases, i.e. the explicit accreditation of the same standard by several national SSOs, allows firms to save on country-specific adaption costs. In addition, the uniformity of product characteristics across countries may increase the marketability of products. For example, producers using 4G mobile phone standards ensure that their products not only work in a wide range of countries but are also compatible with applications such as mobile web access, IP telephony and video conferencing.

The main contribution of this paper is to highlight the release of harmonized, voluntary standards as a novel channel of higher trade integration and to quantify its effect on international trade. By shifting the focus from regulatory to voluntary standards and their harmonization, we depart from the trade literature that views product standards through a regulatory lens. Voluntary standards span beyond the health, safety and environmental aspects usually covered by regulatory standards. Our database includes more than one million standards, of which almost half are harmonized, thereby largely outnumbering the number of regulatory standards commonly found in databases on non-tariff barriers.[1] The release of harmonized standards by SSOs differs from trade policy efforts where governments achieve regulatory convergence through legislative action, either via the explicit harmonization of regulatory standards or mutual recognition.[2]

[1] Over 1995–2014, regulatory standards notified at the WTO cover close to 20,000 standard notifications.

[2] In the former, governments agree to reference another countries' standards or international standards in their legislation. In the latter, regulatory divergence is tackled by allowing the sale of products under both the national and the foreign standards. While such a policy lowers market access costs, the positive

Data limitations have prevented a thorough assessment of the prevalence of product standards (Goldberg and Pavcnik, 2016; Ederington and Ruta, 2016). To construct our novel bilateral product-level database, we track the release and accreditation of foreign and international standards at the document level. We then match our data set with bilateral product-level trade data for 25 industrialized countries and several major emerging economies. Following a difference-in-difference approach, our results show that, on average, standard harmonization increases product-level trade flows by 0.67%. This marginal effect is amplified by the fact that harmonized standards are released in 42% of all bilateral product-level trade flow pairs. Overall, we estimate the average contribution to world trade growth to be 0.27 percentage points per year, which is more than twice the contribution of tariff reductions. Converting our estimates into an ad-valorem equivalent tariff, we obtain values that imply a reduction of 0.16 to 1.58 percentage points.

We provide evidence that the assumptions of our difference-in-difference approach are satisfied and address potential endogeneity concerns. First, we show that there are no significant differences in pre-trends between harmonized and non-harmonized products. In particular, we provide evidence that our results are not driven by the fact that harmonized standards may be primarily released in product categories with larger trade flows or higher growth rates. Second, we mitigate the endogeneity concern that firms' participation in SSOs' activities determine the release of harmonized standards. To this end, we take advantage of the supranational character of so-called European Standards. In addition, we instrument country-specific harmonization events by accreditations of neighboring countries. The estimates of the instrumental variables approach are not significantly different from our baseline OLS estimates, suggesting that the latter estimates are causal.

To shed light on the underlying mechanism, we build a multi-country model of international trade with heterogeneous firms and allow for endogenous standard adoption, i.e. firms decide to produce a standardized or a non-standardized variety of a differentiated product. Product standards capture product attributes, such as quality, compatibility, safety or environmental aspects, which consumers value. Producing standardized varieties requires sunk investment costs and potentially higher marginal costs.[3] The presence of sunk investment costs implies a selection effect where only high-productivity firms choose to produce in accordance with the standard, while low-productivity firms decide to produce the non-standardized variety. The release of a harmonized standard allows for complementarities in sunk investment costs across countries and incentivizes firms to adopt the standard. Because of higher demand for standardized varieties, these firms increase their export sales.

externalities that are created by common, harmonized standards, such as network effects or the reduction of information frictions, cannot be realized.

[3] These features are consistent with recent models on product standards, such as Baldwin et al. (2000), Costinot (2008), Podhorsky (2013), Mei (2017) and Macedoni and Weinberger (2018). The sunk investment costs are similar to "compliance costs" in Maskus et al. (2005), "adaption costs" in Maur and Shepherd (2011) and Toulemonde (2013), "conversion costs" in Gandal and Shy (2001) and "setup costs" in Fischer and Serra (2000). Standards can increase consumer demand because they reduce distortions due to information frictions (Leland, 1979; Atkeson et al., 2014) or create positive network externalities from more users (Katz and Shapiro, 1985; Farrell and Klemperer, 2007).

To provide empirical support for the model's predictions, we use bilateral product-level as well as French firm-level data. First, we investigate the importance of firm-level heterogeneity. Running our baseline specification with a decomposition into the extensive and intensive margin shows that standard harmonization increases trade through higher sales of existing exporters (intensive margin) and has no effect on firm entry (extensive margin). When we split the firm-size distribution into quartiles, only the exporters in the highest quartile increase their sales. For all other quartiles, the effect is not significant. This heterogeneous effect is consistent with the size-dependent selection effect implied by the presence of sunk investment costs. Second, we show that harmonized standards have a larger impact on horizontally and vertically differentiated products for which standardization benefits are expected to be higher. We interpret this set of results as evidence that harmonized standards shift demand towards standardized varieties. Third, we examine the role of market size and trade costs. Harmonization effects are positively related to home market size, have a larger impact on small destination countries and when bilateral trade costs are high. Forth, we investigate the role of national standards and show that trade flows only increase when harmonized standard are released whereas there are no significant effects for national standards.

Related literature The effect of releasing harmonized standards is similar to the mechanism described in the literature on technology and quality upgrading following trade liberalization. Improved access to foreign markets generates scale effects and induces firms to upgrade their quality (Verhoogen, 2008) or technology (Lileeva and Trefler, 2010; Bustos, 2011). Another channel is the cost reduction for intermediate inputs through a reduction in import tariffs that lead to quality upgrading (Amiti and Khandelwal, 2013; Fan et al., 2015; Bas and Strauss-Kahn, 2015).[4] Our model emphasizes an alternative mechanism, where the release of harmonized standards allows for cost complementarities that stimulate investment into product attributes that consumers value. Firms no longer need to pay market-specific adaption costs for the product attribute, similar to the scenario considered by Arkolakis et al. (2016).

The paper also relates to the empirical international trade literature on product standards. While regulatory product standards are usually thought of as trade barriers, the seminal contribution by Swann et al. (1996) shows that standards promote exports. Blind (2004) emphasizes the trade-enhancing effects of standardization through quality improvements and economies of scale.[5] Chen and Novy (2012) also show that standards are associated with lower bilateral trade costs. More recently, Fontagné et al. (2015) and Fernandes et al. (2019) analyze firm dynamics and show that restrictive regulatory standards have a detrimental impact on firm-level export sales and net entry, but less so for larger firms. Macedoni and Weinberger (2018) show that raising the minimum quality level via regulatory standards can improve welfare, if the competition with low-quality firms prevents high-quality firms to produce at the efficient scale.

[4]Alternatively, firms may decide to invest into higher quality only after having learned about demand through experience in the foreign market (Rodrigue and Tan, 2019; Berman et al., 2019).
[5]See Swann (2010) for a literature review on the trade effects of standards.

Some papers analyze specifically the effect of cross-country standard harmonization on trade flows for certain regulations within a subset of industries or countries. Chen and Mattoo (2008) use information on EU/EFTA harmonization and mutual recognition agreements and find that trade flows increase between participating countries, but exports of excluded countries can actually decrease. Disdier et al. (2015) also show that harmonization between Northern and Southern countries is associated with increasing trade flows and point out the trade-deflecting effect on South-South trade. Reyes (2011) shows that the harmonization of EU electronics standards led to an increase of the number of US firms exporting to the EU in that sector.

The increased referencing of product standards in trade agreements (Baldwin, 2011) led to an increase in the number of papers that study the regulatory aspects of harmonizing product standards. For example, Mei (2017) studies the welfare effects of regulatory standards using a quantitative general-equilibrium model. He finds that countries increase their welfare by 12.6% when setting a common harmonized standard. Parenti and Vannoorenberghe (2019) study the decision to coordinate on common product standards within a trade agreement when countries have different regulatory preferences. If divergence in these preferences is small, countries gain from signing a trade agreement featuring standard harmonization. Maggi and Ossa (2019) analyze how the decision to sign such an agreement changes if regulators are subject to industry lobbying. Grossman et al. (2019) study optimal regulatory policies within a trade agreement when products are horizontally differentiated across countries.[6] In this paper, we highlight the parallel effort of SSOs in achieving convergence through the release of common voluntary product standards. These standards change the production structure of firms because their adoption by firms conveys advantages. In contrast, the aforementioned papers focus on mandatory changes through regulatory standards. With respect to trade policy, it is important to mention that more and more preferential trade agreements explicitly refer to voluntary product standards, see McDaniels et al. (2018).

The rest of the paper is organized as follows. Section 2 describes the standard-setting process and Section 3 presents the theoretical framework that we use to derive the regression specification as well as some empirical implications. Section 4 explains the data and stylized facts on cross-country standard harmonization. Section 5 presents the main results before endogeneity concerns and robustness checks are addressed in Section 6. In Section 7, we present empirical evidence on some of the implications of the model while the last section concludes.

2 Motivating facts on standard-setting

Standards are released by different standard-setting organizations (SSOs). An SSO can be organized at the national level (for example, the German Institute for Standardization, DIN, or the Standards Council of Canada, SCC), can be an international standard-setting

[6]For a theoretical discussion of the introduction of *non-harmonized* standards and their impact on trade flows, see Gandal and Shy (2001), Fischer and Serra (2000), Ganslandt and Markusen (2001).

body (such as the International Organization for Standardization, ISO) or an industry association (such as the Institute of Electrical and Electronics Engineers, IEEE). Many SSOs are non-profit, non-governmental organizations. SSOs elaborate standards in working groups and technical committees that are composed of industry experts. For example, in ISO, there are technical committees (TC) on a variety of issues such as screw threads (ISO/TC 1), cosmetics (ISO/TC 217) or blockchain technologies (ISO/TC 307). The experts in those committees participate and vote on the release of standards on behalf of private firms, non-governmental and governmental agencies (Spulber, 2019). Over the last decades, SSOs increasingly release standards originally developed by international SSOs, thereby ensuring the uniformity of technical and product specifications across countries.[7]

One can distinguish between quality standards (i.e. the composition of dental implants or ISO 9000 quality management), compatibility standards (i.e. screw threads or wifi technology), conformity assessment standards (i.e. car safety crash tests or guidelines for personal data protection) or technical standards (i.e. the QWERTY keyboard or the file format used for 3D printing).[8] A standard can be categorized into more than one of these types and the standards in our database actually often fulfill several of these purposes.

The standards released by SSOs are often called consensus standards. They are voluntary[9] but can become legally binding through government regulation. For example, the standard IEC 331:1970 that deals with fire-resisting characteristics of electrical cables has been incorporated by reference into the U.S. Code of Federal Regulations. While our database does not allow us to identify regulatory standards, we can get an estimate for the relative magnitudes of regulatory and voluntary standards for the US: when restricting our sample to SSOs that can be found in a database of regulatory US standards, the latter comprise in number less than 5% of the number of documents in our database.[10]

[7] Alternatively, a national SSO (i.e. in Canada) can also accredit a standard that was originally developed by a SSO of another nationality (i.e. the US). Of all accreditations that we observe in our dataset, only 6% concern this latter form of harmonization whereas the remainder concerns the accreditation of international standards.

[8] There exists no official categorization of the different standard types. See for example the discussion in Swann (2000). The standard ISO 22794:2007 describes materials to be used in dental implants and how to evaluate their performance. ISO 9000 is a standard family for quality management. ASME B1.1-2003 describes dimensions for screw threads used in the US and Canada. IEEE 802.11 is the most well known wifi standard. ISO 7862:2004 defines test procedures for the evaluation of restraint systems in passenger cars that can be used in crash tests. BS 10012:2017 describes data protection guidelines for the management of personal information. INCITS 154-1988[S2009] describes the arrangement of the keys and the respective characters of computer keyboards commonly used in North America. ISO/ASTM 52915 specifies the additive manufacturing file format (AMF) that is used in 3D printing technology.

[9] For example, the International Organization for Standardization (ISO) stresses that its standards are voluntary. In a similar vein, European standards, even though sometimes requested by the European Commission, remain voluntary. In certain instances, standards are elaborated to support and interpret government regulation, but their use often remains voluntary.

[10] We obtain data from the National Institute of Standards and Technology's database on Standards Incorporated by Reference (SIBR) which tracks standards that are incorporated into US federal regulation and are therefore mandatory. When restricting our database to US SSOs that we can match to the SSOs in SIBR, our database comprises 226,482 documents while the equivalent number in SIBR is only 10,696 (4.7%). We are not able to match the databases on the document level and can only compare the aggregate number of documents per SSO.

Shifting the focus on voluntary rather than regulatory standards also implies that we cover a larger number of products, thus extending beyond health, safety or environmental aspects that typically make up regulatory trade barriers. By way of comparison, regulatory standards notified to the WTO[11] amount to 19,823 measures over the period 1995–2014 while our database contains roughly 1.1 million standard documents of which 530,645 are harmonized standards (the database is described in detail in Section 4).[12] This difference highlights the extent and effort of countries to establish common product features though voluntary standards.

The voluntary nature of the bulk of standardization activity has important implications for the underlying economic mechanisms. Governmental intervention in the form of *regulatory* standards is often associated with tackling market failures caused by the presence of negative externalities, where consumers do not take into account certain product features (e.g. goods produced with highly polluting technologies).[13] On the contrary, *voluntary* standards define product attributes that users value, otherwise producers have little incentives to use the standard. Internet protocols, railway gauges or financial service standards are examples of how compatibility standards increase consumer utility by generating network externalities and scale effects. Standards can also reduce distortions due to information frictions. For example, the labeling and certification of agricultural products allows consumers to distinguish high from low quality. Similar arguments apply to technical standards that producers of highly complex, technological products can simply refer to instead of using extensive product descriptions (i.e. for electronics or pharmaceuticals). Consumer preferences for a certain attribute can result in voluntary standards becoming *de facto* binding. In this case, consumer demand guides firms in the production of goods. For example, consumers expect a printer to be compatible with A4 paper size (ISO 216:2007) or letter size (ANSI/ASME Y14.1) despite there being no official law on paper dimensions for printers.

We incorporate the above described elements into our theoretical framework below. First, we consider product standards as product attributes that consumers value (though compliance with a standard involves sunk investment costs). Second, our model features endogenous standard adoption by firms who decide whether to produce according to a voluntary standard or not.

[11]WTO member countries are required to notify to the WTO any release of a regulatory standard that concerns a tradable product or service and is not an international standard, see Article 2 of the WTO Agreement on Technical Barriers to Trade.

[12]The public versions of the WTO's Sanitary and Phytosanitary Information Management System (SPS IMS) and Technical Barriers to Trade Information Management System (TBT IMS) do not contain the name or identifier of the regulatory standard, preventing us from matching it to our database.

[13]Regulatory standards can be issued for other reasons than addressing a negative consumption externality. For example, "regulatory protectionism" (Grossman et al., 2019) or allocation inefficiencies due to excessive entry (Macedoni and Weinberger, 2018).

3 Theoretical framework

General set-up. Our theoretical framework is a modified version of the Melitz (2003) - Chaney (2008) framework. Heterogeneous firms face a sector k-specific CES demand with elasticity of substitution σ_k, fixed costs of exporting from country i to country j, f_{ijk}, as well as variable iceberg trade costs τ_{ijk}. Quantities exported from country i to country j in sector k are denoted by c_{ijk}. Consumption in j is given by a CES basket:

$$C_{jk} = \left[\sum_{i=1}^{N} \int_{\omega \in \Omega_{ijk}} [z_{ijk}(\omega) c_{ijk}(\omega)]^{\frac{\sigma_k - 1}{\sigma_k}} \, d\omega \right]^{\frac{\sigma_k}{\sigma_k - 1}} \tag{1}$$

The term $z_{ijk}(\omega)$ captures the voluntary product standard that is applied to exporters from i selling to country j in sector k. The term z_{ijk} acts as a demand shifter that translates these product attributes into demand equivalents. On the one hand, we can think of z_{ijk} as capturing horizontal differentiation where $z_{ijk} > 1$ indicates that consumers value a product more if it corresponds to their ideal product attribute. Thus, two products might be characterized by the same level of quality (think of A4 and letter size for paper formats), but consumers in different countries might value them differently, according to their preferences. Alternatively, we can also incorporate vertical differentiation. In this case, standards enable consumers to better assess product attributes through certification or labelling and $z_{ijk} > 1$ captures the quality level.[14]

For aggregate demand, we assume that demand for goods produced in different sectors k is determined by the following utility function:

$$U_j = \sum_{k=0}^{K} \alpha_k \log C_{jk} \quad , \qquad \sum_{k=1}^{K} \alpha_k = 1 \; , \quad \alpha_k > 0 \tag{2}$$

Expenditure in sector k, X_{jk}, is therefore given by a fraction α_k of total income Y_j. From the consumer maximization problem, we can derive demand for variety-specific exports from country i to country j in sector k, given by:

$$c_{ijk}(\omega) = A_{jk} z_{ijk}(\omega)^{\sigma_k - 1} p_{ijk}(\omega)^{-\sigma_k} \tag{3}$$

where $A_{jk} = P_{jk}^{\sigma_k - 1} X_{jk}$ summarizes destination-specific sector demand and the corresponding price index, which is defined as follows:

$$P_{jk} = \left(\sum_{i=1}^{N} \int_{\omega \in \Omega_{ijk}} \left[\frac{p_{ijk}(\omega)}{z_{ijk}(\omega)} \right]^{1-\sigma_k} d\omega \right)^{\frac{1}{1-\sigma_k}} \tag{4}$$

Firms maximize profits by choosing prices given the product standard $z_{ijk}(\omega)$. Firm costs

[14] We intentionally abstract from modelling the role of regulatory standards in reducing negative consumption externalities as it is the case in the models of Parenti and Vannoorenberghe (2019), Maggi and Ossa (2019) or Costinot (2008). Instead, we focus on the release of voluntary standards by SSOs that encourage firms to invest into product attributes that consumers value.

are affected by z_{ijk} in two ways. First, the implementation of a product standard $z_{ijk}(\omega)$ necessitates sunk investment costs $a(z_{ijk}(\omega))$. These capture the idea that a product standard requires firms to change existing production structures to produce the product specifications outlined in the standard document (see Shepherd, 2007). Second, marginal production costs $z_{ijk}^{t_k}(\omega)$ can also depend on the product attributes. In the case of vertical differentiation, the parameter $t_k \in (0,1)$ captures the elasticity of marginal costs with respect to the standard and assures that marginal costs (and thus the price that firms charge) rise with higher quality. In the case of horizontal differentiation, $t_k = 0$ implies no additional marginal costs and the variable $z_{ijk}(\omega)$ simply acts as a demand shifter that signals consumer preferences for one product attribute rather than another.

Firms face variable iceberg costs of exporting τ_{ijk} as well as fixed costs of exporting f_{ijk}. They differ in their productivity φ to produce their respective variety and choose whether to produce the standardized or non-standardized variety.[15] If a firm chooses to produce in accordance with the standard, it receives additional demand $z_{ijk} > 1$ which is the same for all firms producing the standard. Firms that choose not to produce in accordance with the standard receive no additional demand, thus $z_{ijk} = 1$. Firms' profits are:[16]

$$\pi_{ik}(\varphi) = \sum_{j=1}^{N} p_{ijk}(\varphi)c_{ijk}(\varphi) - \frac{\tau_{ijk} z_{ijk}^{t_k}(\varphi)}{\varphi} c_{ijk}(\varphi) - f_{ijk} - a(z_{ijk}(\varphi)) \tag{5}$$

Firms then choose their optimal price given the product standard, demand and their idiosyncratic productivity:

$$p_{ijk}(\varphi) = \frac{\sigma_k}{\sigma_k - 1} \frac{\tau_{ijk} z_{ijk}^{t_k}(\varphi)}{\varphi} \tag{6}$$

Substituting for product demand and the optimal price, we obtain firm export sales $x_{ijk}(\varphi)$ and profits $\pi_{ijk}(\varphi)$:

$$x_{ijk}(\varphi) = A_{jk} \left(\frac{\sigma_k}{\sigma_k - 1} \frac{\tau_{ijk}}{\varphi} \frac{z_{ijk}^{t_k}(\varphi)}{z_{ijk}(\varphi)} \right)^{1-\sigma_k} \; ; \; \pi_{ijk}(\varphi) = \frac{x_{ijk}(\varphi)}{\sigma_k} - f_{ijk} - a(z_{ijk}(\varphi)) \tag{7}$$

Endogenous standard adoption. Our benchmark is a situation where the respective SSO in each country issues a national k-specific product standard. For ease of exposition, we consider a two-country world ($N = 2$). The two countries are denoted by subscripts i and j. Firms can choose whether to export a standardized product (we denote those firms with the superscript n) or whether to export a non-standardized product (no superscript). We focus on the case where consumers value only products that are in accordance with the standards released by their respective national SSOs, while they ignore product attributes

[15] Given that each firm is producing a distinct variety, we can index varieties (ω) by firm productivity (φ).
[16] Without loss of generality, we normalize the sector-specific factor price of labor input to one.

that are prescribed by foreign standards, i.e. $z_{ijk} = z_{jk}$.[17] Standardizers have to pay the sunk investment costs $a(z_{jk})$, whereas non-standardizers do not pay any investment costs but forego demand effects:

$$\begin{array}{lll} \text{Standardizers:} & z_{ijk} = z_{jk} > 1; & a(z_{jk}) > 0 \\ \text{Non-standardizers:} & z_{ijk} = 1; & a(z_{jk}) = 0 \end{array} \tag{8}$$

The presence of sunk investment costs introduces a selection effect that results in only high-productivity firms willing to produce the standardized variety (the conditions of this partitioning are similar in spirit to those in Melitz (2003), and are derived in Appendix A). As a consequence, there are two export cut-offs. The first cut-off ($\bar{\varphi}$) designates the firm that is indifferent between entering the export market or not. The second cut-off ($\bar{\varphi}^n$) designates the exporter that is indifferent between exporting the standardized variety or non-standardized variety.[18] The firm has to weigh the sunk investment costs to produce according to the standard z_{jk} against the additional demand for standardized products ($s(z_{jk}) = z_{jk}^{(\sigma_k-1)(1-t_k)} - 1$) relative to non-standardized products. The two export cut-offs are given by:

$$\bar{\varphi}_{ijk} = \left(\frac{\sigma_k f_{ijk}}{A_{jk}}\right)^{\frac{1}{\sigma_k-1}} \frac{\sigma_k}{\sigma_k - 1}\tau_{ijk} \tag{9}$$

$$\bar{\varphi}^n_{ijk} = \left(\frac{\sigma_k a(z_{jk})}{s(z_{jk})A_{jk}}\right)^{\frac{1}{\sigma_k-1}} \frac{\sigma_k}{\sigma_k - 1}\tau_{ijk}. \tag{10}$$

Next, we can write total bilateral export sales of country i to country j as the sum of the sales of firms that produce the standardized varieties (firms with productivity in the interval $\bar{\varphi}^n < \varphi < \infty$) and firms that produce the non-standardized variety (firms with productivity in the interval $\bar{\varphi} < \varphi < \bar{\varphi}^n$).[19] Assuming a Pareto distribution over the interval $[1, \infty]$ with product-specific shape parameter ξ_k, we write product-specific bilateral trade flows as:

$$X^n_{ijk} = \left(\frac{\sigma_k}{\sigma_k - 1}\tau_{ijk}\left(\sigma_k \frac{f_{ijk}}{A_{jk}}\right)^{\frac{1}{\sigma_k-1}}\right)^{-\xi_k} \Gamma_k f_{ijk}\left(1 + s(z_{jk})\Delta^n_{ijk}\right) \tag{11}$$

[17] We also consider a version of the model where consumers value standards from the exporting country similar to Podhorsky (2013). This extension, available upon request, changes the trade-off between national and harmonized standards but the main empirical implications of our simplified model remain valid. Grossman et al. (2019) consider the case of horizontal differentiation and assume that the demand shifter depends on the distance between a product's characteristics and consumers' ideal product attributes. In our model, consumers only value product attributes that exactly match their national standard. This assumption is especially realistic for compatibility standards: a screw thread or an electric adapter have to comply exactly with a standard specification, just being close to the specification has no value-added.

[18] If the additional demand from producing the standardized variety is large enough, i.e. the marginal exporter finds it worthwhile to produce in according with the standard, there exists only one exporter cut-off productivity. Given that are empirical estimates support the view of two productivity cut-offs, we focus in our discussion on this case.

[19] The detailed aggregation can be found in Appendix A.

where $\Gamma_k = \frac{\xi_k \sigma_k}{\xi_k - (\sigma_k - 1)}$. The release of a voluntary national standard increases bilateral trade flows because of higher demand captured by $s(z_{jk})$; this is reflected in the share of exporters that decide to produce in accordance with the foreign standard

$$\Delta^n_{ijk} = \left(\frac{s(z_{jk}) f_{ijk}}{a(z_{jk})} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1}. \tag{12}$$

Harmonized product standards. Instead of issuing national standards, the SSOs in country i and j may decide to issue a common harmonized standard z_k that is equivalent in both countries. The advantage of issuing harmonized standards is that they allow for cost complementarities in sunk investment costs across markets, i.e. a firm has to pay the sunk investment cost $a(z_k)$ once and benefits from higher demand in both markets. Based on this assumption, firms that choose to invest in the harmonized standard (superscript h) pay the sunk investment costs $a(z_k)$ whereas non-standardizers do not pay any investment costs but forego demand effects:

$$\begin{array}{lll} \text{Standardizers:} & z_{ijk} = z_k > 1; & a(z_k) > 0 \\ \text{Non-standardizers:} & z_{ijk} = 1; & a(z_k) = 0 \end{array} \tag{13}$$

As in the case with national standards, there are two export cut-offs. The first cut-off $(\bar{\varphi})$ designates the firm that is indifferent between entering the export market or not and is given by equation 9. The second cut-off $(\bar{\varphi}^h)$ designates the exporter that is indifferent between exporting the harmonized standardized variety or the non-standardized variety:

$$\bar{\varphi}^h_{ijk} = \left(\frac{\sigma_k a(z_k)}{s(z_k) \left(A_{ik} + A_{jk} \tau_{ijk}^{1-\sigma_k} \right)} \right)^{\frac{1}{\sigma_k - 1}} \frac{\sigma_k}{\sigma_k - 1} \tag{14}$$

The cut-off productivity under harmonization highlights the cost complementary via the inclusion of the domestic market size A_{ik}. A larger home and destination market reduces the importance of the sunk investment costs and encourages more firms to invest into the product standard. The mechanism is similar to Lileeva and Trefler (2010) and Bustos (2011) with the difference that, in our model, investment is incentivized through cost complementarities rather than improved market access through lower tariffs.

Following the previous aggregation steps and using the assumption on the Pareto distribution, we can write bilateral trade flows under harmonized standards as follows:

$$X^h_{ijk} = \left(\frac{\sigma_k}{\sigma_k - 1} \tau_{ijk} \left(\sigma_k \frac{f_{ijk}}{A_{jk}} \right)^{\frac{1}{\sigma_k - 1}} \right)^{-\xi_k} \Gamma_k f_{ijk} \left(1 + \Delta^h_{ijk} s(z_k) \right) \tag{15}$$

where Δ^h_{ijk} captures the share of firms that invest into the harmonized standard

$$\Delta^h_{ijk} = \left(\frac{s(z_k) f_{ijk} \left(A_{ik} + A_{jk} \tau_{ijk}^{1-\sigma_k} \right)}{a(z_k) A_{jk} \tau_{ijk}^{1-\sigma_k}} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1} \tag{16}$$

and the term $s(z_k)$ describes the associated demand effect. Equation 15 shows the impact of standard harmonization on bilateral trade flows and forms the basis for our empirical analysis.

Product standardization through cost complementarities. Before discussing the estimation equation, we briefly compare the effects of harmonized and national standards on bilateral trade flows. The difference between the former and the latter depends on two effects (their analytical expressions can be found in Appendix A). The first effect is the *cost complementarity effect* and is always higher for harmonized standards. The reason is that harmonized standards allow for complementarities in sunk investment costs, thereby reducing market-specific investment costs and inducing more firms to produce in accordance with the standard. This implies that, for a similar level of product attribute ($z_k = z_{jk}$), the share of exporters producing the standardized variety is always higher ($\Delta^h_{ijk} > \Delta^n_{ijk}$). To the extent that adapting a product standard is very costly, especially in relative terms for small export markets (high $a(z_{jk})$ compared to low A_{jk}), these smaller markets profit from harmonized standards to a larger extent, potentially passing from a situation where none of the firms sell standardized varieties in these markets to a situation where a large share of them do.

The second effect is the *demand effect*. It captures the extent to which consumers value harmonized standards z_k differently from national standards z_{jk} and can be positive or negative. For example, if the harmonized standard allows for positive network effects (think of phone devises that work both in the US and Europe), consumers may value these products more than a potential national version. If, on the other hand, the harmonized standard does not comply with national preferences (think of US "chlorinated chicken" exports to Europe), the demand effect might be smaller under harmonized standards. The cost complementarity effect could still outweigh any potential demand effect, but it is essentially an empirical question which we address more closely in Section 7.4.

Estimation equation. Next, we derive the empirical estimation equation for bilateral product-specific trade flows. We opt for this empirical strategy as it is not possible to identify the firms that choose to produce in accordance with a product standard. The main advantages of focusing on the product-level are that (1) we can include a rich set of fixed effects that allow us to simultaneously control for demand and supply conditions and (2) we can quantify aggregate effects as well as the contribution of standard harmonization to changes in global trade. The main disadvantage is that the product-level data do not allow us to investigate the model implied selection effect at the firm-level. For this reason, we corroborate our empirical analysis with firm-level evidence from France.

Our baseline estimation equation consists of a difference-in-difference approach and compares trade flows whose products were subject to a harmonization event with those that were not. Taking logs of our gravity equation 15, our estimation equation takes the following form:

$$\log X_{ijk} = \beta h_{ijkt} + f_{ijk} + f_{ikt} + f_{ijt} + f_{jkt} + e_{ijkt} \tag{17}$$

where the log of bilateral exports of a product k is a function of a dummy variable h_{ijkt}

that captures the changes in the gravity equation due to harmonization. h_{ijkt} is a dummy variable that equals one whenever there is at least one standard that the importing country j harmonizes with the exporting country i in product k at time t.[20] Since our panel dataset allows us to compare harmonization events for different products in different countries, we include destination-specific (f_{jkt}), origin-specific (f_{ikt}), time-varying bilateral (f_{ijt}) and time-invariant bilateral product characteristics (f_{ijk}). These set of fixed effects capture differences in product-specific destination market size that varies over time (A_{jkt}), the total number of exporters from country i in product k in a given year t (M_{ikt}) and time-invariant bilateral trade costs at the product-level (f_{ijk} and τ_{ijk}). We later relax this assumption and include observable changes in trade costs as a control variable.

The coefficient of interest $\hat{\beta}$ measures the change in the trade flows due to standard harmonization and equals the average increase in firm-demand $\bar{s}(z_k)$ times the share of firms that choose to produce in accordance with the standard $\bar{\Delta}^h$. Our identification strategy therefore consists in a relative comparison between trade flows that are subject to harmonized standard releases and those that are not. The coefficient $\hat{\beta}$ measures the cross-sector average which is dependent on the distribution of structural parameters across sectors, such as the firm-size distribution, trade costs as well as home and destination market size (see equation 15). These empirical implications will be discussed in detail in Section 7.

4 Data

We track the standard releases of each SSO in the Searle Center Database on Technology Standards, Industry Consortia and Innovation (Baron and Spulber, 2018), and use information on standard equivalences in order to identify cross-country standard harmonization. The data set contains the date of release, the International Classification for Standards (ICS) category and the nationality of the SSO. A SSO can release a standard developed by its own technical committee, but can also release a standard developed by another SSO.[21] In order to identify relevant harmonization events, we restrict the sample to those standards that constitute the first publication ("original") across all SSOs/nationalities as well as the accreditation of these original standards by SSOs of different nationality.

In our dataset, there are two means via which product standards are harmonized across countries. Either a SSO decides to accredit the standard of a SSO of another nationality or two SSOs of different nationality accredit a standard originating in an international SSO. Of all accreditations that we observe in our database, 6% concern the accreditation of a standard that was originally released by a national SSO while the bulk of all accreditations,

[20] Note that our baseline specification does not exploit the number of standard documents that have been harmonized within a year. The reason is that a higher number of harmonized standards within the product group does not necessarily imply that the economic effect of harmonization should be larger. This argument is supported by our analysis. Including the log of the number of harmonized documents as an additional control variable does not have a significant effect on our results.

[21] This is for example the case when a standard released by an international SSO such as the International Organization for Standardization (ISO) is published by a national SSO such as the British Standards Institution (BSI).

i.e. 94%, concern international standards. A large amount of this international dimension of standard harmonization is due to the European integration process and the accompanying dominance of European SSOs among international SSOs. National SSOs play only a minor role (see Appendix C for more details on the number of original standards and accreditations in our dataset as well as the prevalence of international SSOs).

In the data, we define harmonization as follows: a SSO of the importing country releases a standard that was also released by a SSO of the exporting country (either in the same year or before).[22] Our definition of standard harmonization comprises both standard releases that concern aspects which were previously not subject of a product standard (either because there was no standard or because the product/technology did not yet exist) or standard harmonization in the strict sense where conflicting standards are replaced by one common, harmonized version. We designate the term "standard harmonization" to apply both to the release of a new, harmonized standard as well as to the replacement of conflicting standards.

In terms of sectoral heterogeneity, standards are categorized according to the International Classification for Standards (ICS).[23] Table 1 shows that cross-country standard harmonization is very prevalent in materials technologies, electronics and ICT as well as engineering technologies. Note that a standard can be classified into more than one ICS category.

Table 1: Releases of harmonized standards, by major ICS categories

Field	Number	in %
Agriculture and food technologies	26309	3.3
Construction	80694	10.1
Electronics, information technology and telecommunications	130109	16.3
Engineering technologies	135966	17.0
Generalities, infrastructures and sciences	88337	11.0
Health, safety and environment	89568	11.2
Materials technologies	135906	17.0
Special technologies	28324	3.5
Transport and distribution of goods	84707	10.6
Total	799920	100

Notes: The table displays the number of standard releases, broken down by major ICS categories, after having excluded within-country accreditations. The categories are Agriculture and food technology [ICS 65–67]; Construction [ICS 91–93]; Electronics and ICT [ICS 31–37]; Engineering technologies [ICS 17–29 and 39]; Generalities, infrastructures and sciences [ICS 01–07]; Health, safety and environment [ICS 11–13]; Materials technologies [59–61 and 71–87]; Special technologies [95–97]; and Transport and distribution of goods [ICS 43–55]. A number of standards belong to more than one ICS class (disaggregated at the 5-digit level). The data are summed over the years 1995–2014 and all SSOs.

[22]With respect to mutual recognition, we are not able to identify these events in the data. This would require knowing that the accreditation of a trading partner's standard was specifically part of a mutual recognition procedure. An alternative form of mutual recognition, as in the case of the EU, does not necessarily involve the formal accreditation of a trading partner's product standards and consequently does not show up in our dataset.

[23]See the table in Appendix B for the first level of disaggregation of the ICS.

The next step is to relate the standard documents to products traded in international markets. The data source for bilateral product trade flows is the BACI database developed by the CEPII; see Gaulier and Zignago (2010). BACI reconciles export and import declarations of values and volumes in the United Nations COMTRADE database by giving precedence to countries with more reliable trade statistics. International trade flows are classified according to the Harmonized System (HS) established by the World Customs Organization (WCO) with standardized 6-digit codes common to all countries. On the contrary, product standards are classified according to the International Classification for Standards (ICS) system. The non-existence of a concordance between these two classifications is one of the main reasons why previous papers in the literature cover only certain sectors: see Moenius (2006), Reyes (2011) or Fontagné et al. (2015).

We tackle the concordance issue in two ways. First, we use a newly developed concordance table from the WTO with the drawback that some links between key standard categories and products might be missing (see Appendix D for more details). As a second step, we develop a new all-industry concordance table using keyword-matching techniques and describe our methodological approach in a companion paper (Han et al., 2019).[24] The main advantage of this table is that it covers all ICS and HS categories. Both concordance tables create links between the 5-digit ICS standard categories and 4-digit HS product categories. We link the standard harmonization events at the country-pair level to the corresponding product and aggregate all harmonization events within an HS 4-digit product (1250 different categories). The resulting dataset varies by exporter, importer, product and year and is the basis for our empirical analysis. The final sample size consists of all bilateral sector linkages between the 26 countries[25] for the period 1995-2014 and results in 6.7 million observations with a positive trade flow. Of these observations, 44% are subject to at least one standard harmonization.

Having discussed the data and the correspondence table to link product standards to trade flows, we now present the empirical results based on the regression specification discussed in Section 3. The results are based on the WTO concordance table, while the results using the concordance based on keyword-matching techniques can be found in Appendix E. At this point, we want to stress that even though our standard database is a comprehensive database covering the most important industrialized and emerging countries, we cannot exclude under-reporting for specific countries or standard setting organizations. Our regression specification includes time-varying product-specific fixed effects for exporting and importing countries to minimize the risks from under-reporting. As we measure the explicit release of harmonized standard documents, our results should thus be interpreted as pertaining explicitly to *formal* harmonization.

[24]We describe the details of both approaches in Appendix D.

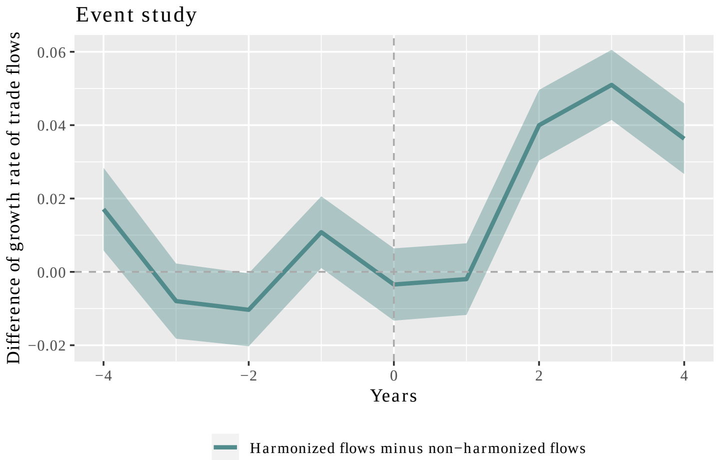
[25]These countries are Australia, Austria, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Italy, Jordan, Japan, Korea, Netherlands, Norway, Poland, Russia, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States.

5 Results

5.1 Baseline results

Harmonized standards are generally associated with a positive overall impact on trade flows. A first glance at the data confirms this intuition. We calculate the average growth rate of trade flows before and after a harmonization event and compare it with the growth rate of trade flows that were never subject to standard harmonization. The difference between the two is plotted in Figure 1. One notices a significantly higher growth rate for bilateral exports after the importer accredited the same standard as the exporter. Before the harmonization event, we do not observe any significant differences in the growth rates between the treatment and the control group.

Figure 1: Growth of trade flows around harmonizations



Notes: This figure plots the mean growth rate before and after a harmonization event for harmonized trade flows (treatment group) and non-harmonized trade flows (control group). Only the first harmonization event for each exporter-importer-product combination is considered. The control group only comprises exporter-importer-product combinations that were never harmonized. The point 0 denotes the timing of the event. The sample covers the years 1999–2010 and has been restricted to only include observations with positive trade flows in the preceding four years. Growth rates below the 2.5th and above the 97.5th percentiles are excluded from the calculations.

To provide more formal evidence on the relationship plotted in Figure 1, we start by estimating regression equation 17 and add different sets of fixed effects and tariffs as a control variable. For the latter, we use the simple average applied tariff rate from the World Integrated Trade Solution (WITS) TRAINS dataset from the World Bank. Column (3) and column (4) are our preferred estimates as they include the full battery of fixed effects. Column (3) in Table 2 confirms the suggested positive effect of harmonized standard releases on trade flows in Figure 1. The estimated coefficient of 0.0067 is statistically significant at the 1% level and implies that, on average, a harmonization event increases bilateral trade flows by 0.67%. Column (4) adds observed bilateral product-level tariff rates in the importing country j as an additional control variable. The point estimate in this specification is slightly lower than in column (3) with 0.0049 but still significant at the 1% level. Column (1) and column (2) in Table 2 show the importance of controlling for

Table 2: Regression results / Baseline specification

	(1) Total	(2) Total	(3) Total	(4) Total
Harm.	0.15050***	0.02121***	0.00667***	0.00489***
	[0.000]	[0.000]	[0.000]	[0.008]
Ln(1+tariff)				-1.71290***
				[0.000]
Observations	5920146	5848858	5848855	4692952
R^2	0.22	0.88	0.88	0.89
Adjusted R^2	0.22	0.85	0.85	0.86

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Fixed effects are included as described in the regression specification 17. The number of observations changes because of multicollinearity when including more fixed effects. Standard errors are clustered at the exporter-product-level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

unobserved characteristics. Without controlling for product-specific effects, the estimated effect would be 20 times larger and 3 times larger if we did not control for time-varying bilateral effects such as signing a preferential trade agreement or any other aggregate changes in the bilateral trade relationship.

5.2 Ad-valorem equivalents and contribution to growth in world trade

How does the increase in trade flows from standard harmonization compare to observable trade costs? To answer this question, we calculate the ad-valorem equivalent (AVE) of tariffs following Kee et al. (2009). They define the ad-valorem equivalent (AVE) in non-tariff measures (in our case, harmonized standard releases) as the equivalent of the ad-valorem tariff rate that induces the same proportionate change in the value traded adjusted by the import demand elasticity (σ):

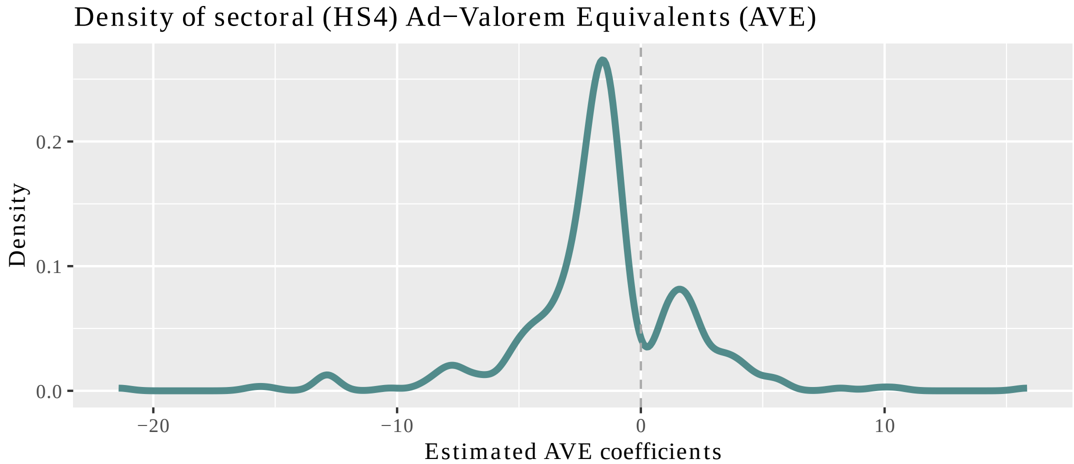
$$AVE = \left(\frac{\exp(\beta) - 1}{\sigma} \right) 100. \tag{18}$$

To obtain an estimate of the aggregate AVE, we consider two approaches. First, we take the estimate of the harmonization dummy in column (4) of table 2 for β and the estimated coefficient of the average applied tariff rate minus one for the import demand elasticity. Second, to address potential endogeneity concerns with respect to the import demand elasticity, we use the value 4 from Head and Mayer (2014) for the import demand elasticity and the baseline estimate of the harmonization dummy in column (3) of table 2 for β. These values imply that the aggregate AVE ranges between -0.16 to -0.18, which we interpret as an implicit export subsidy in the range of 0.16 to 0.18 percentage points.

In addition, we exploit the sectoral dimension and compute product-specific ad-valorem equivalents. Given the similarities in the aggregate AVE, we focus only on the approach that uses estimates from the literature for the import demand elasticity. Including the full set of fixed effects, the product-specific estimation equation is written as

$$\log(X_{ijt}^k) - \sigma_k \log(1 + t_{ijkt}) = \beta_{1,k} h_{ijt}^k + f_{it} + f_{jt} + f_{ij} + \varepsilon_{ijt}. \tag{19}$$

Figure 2: Ad-Valorem Equivalents (AVE)

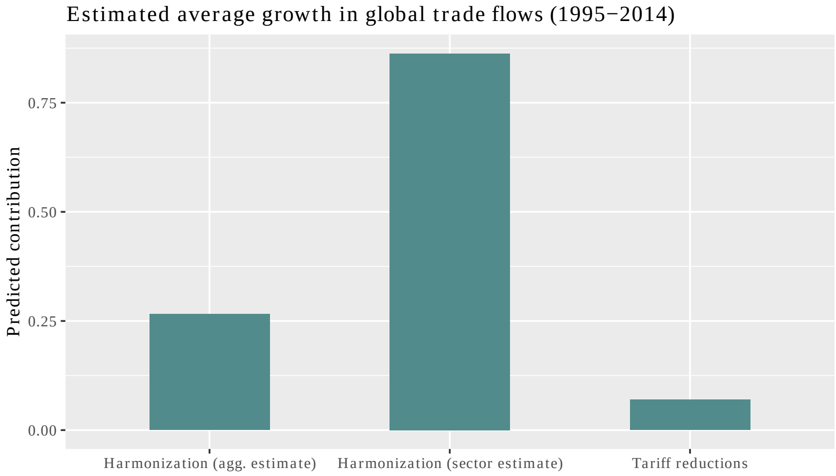


Notes: This figure plots the kernel density estimate of the product-specific AVE estimates at the HS 4-digit level. Only statistically significant AVE estimates are included in the plot.

Using the 4-digit HS import demand elasticity estimates from Soderbery (2018) for σ_k, we estimate equation 19 for each 4-digit HS sector. Taking the obtained product-specific estimates of harmonized standards $\hat{\beta}_k$ in combination with the "delta method", we compute the point estimate of the AVE together with the standard errors. Figure 2 shows that there is significant heterogeneity across the 915 different HS 4-digit products. For the majority of sectors, a standard harmonization event increases trade flows and implies a negative ad-valorem equivalent tariff rate. The cross-sector average is -0.87, significantly lower than the aggregate AVEs of -0.16 and -0.18 based on table 2. This difference is explained by the fact that the estimated harmonization coefficients tend to be larger for sectors with a low import demand elasticity, a point we discuss in more detail in Section 7.2. When taking into account only those sectoral estimates that are significant, we obtain an average AVE of -1.58. Overall, our AVE estimates suggest that the effect of harmonized standard releases corresponds, on average, to a subsidy ranging from 0.16 to 1.58 percentage points.

Next, we use the point estimates of the harmonization indicator to calculate the implied increase in total trade flows among the countries in our sample. We simply multiply the harmonization dummy by either (1) the point estimate of the full sample in column (4) of Table 2 or (2) the sector-specific point estimates of regression 19 and calculate the trade-weighted average increase in trade flows between the countries in our sample. Figure 3 plots the estimated increase due to standard harmonization for both set of estimates. Based on the aggregate coefficient ("agg. estimate"), the average implied increase is 0.27%, while the sectoral coefficients imply an increase of 0.73% of trade flows ("sector estimate"). Given that the average growth rate of trade in our sample is 5.9%, these estimates suggest that up to 12.4% of this increase is due to standard harmonization. The reason for this considerable contribution despite the low point estimates is that 44% of our products are harmonized within a given year. For comparison, we also include the implied change in trade flows due to tariff reductions. The associated increase is smaller, amounting to only 0.12%. Overall, these estimates reveal that standard harmonization among the countries in our sample contributed significantly more to world trade growth than tariff reductions.

Figure 3: Increase in trade flows due to standard harmonization



Notes: This figure plots the contribution of standard harmonization and tariff changes to the growth rate of trade flows among the countries in our sample.

6 Endogeneity and robustness

This section addresses potential identification concerns and endogeneity issues. The first identification concern is that harmonization primarily happens in product categories where trade flows are generally large; higher trade flows after the release of harmonized standards are thus simply a result of the preference of SSOs to standardize more important product categories. This would violate the assumption of parallel pre-trends in our difference-in-difference setting. Second, special interest groups or firms may lobby for the accreditation of a standard in the anticipation of higher sales. In order to address these concerns, we want to point out that all our regressions include a rich set of fixed effects that controls for any non-discriminatory or regulatory standards common to all exporters or importers. Below, we resort to several robustness tests, namely (1) estimating our regression model in differences and including product-specific bilateral time trends, thus ruling out the size and growth effect of large trade flows, (2) testing for the existence of pre-trends, (3) assuring that the standards in question have a supranational and thus largely exogenous character (by testing so-called European Standards) and (4) using the harmonization events of neighboring countries as an instrument for a country's own events. Finally, we briefly mention additional robustness tests that we report in Appendix E.

6.1 Difference equation

One key identification concern is that our main results in Table 2 are driven by the fact that standard harmonization is primarily done in sectors where exporters are already present and where trade volumes are high. To address part of these concerns, we specify our baseline regression in terms of first differences:

$$\Delta X_{ijkt} = \beta \Delta h_{ijkt} + f_{ikt} + f_{jkt} + f_{ijt} + f_{ijk} + \varepsilon_{ijkt} \tag{20}$$

and include controls for product-specific bilateral time trends (f_{ijk}). These fixed effects account for the identification concern that countries may harmonize standards for trade flows that grow, on average, at a higher rate. The variable of interest, Δh_{ijkt}, is the first difference of the cumulative measure of standard harmonization h_{ijkt}. Δh_{ijkt} is a binary indicator that equals one in the year the standard harmonization took place and zero otherwise. In addition, we follow Baier et al. (2014) and allow for multi-year differences. The regression equation looks as follows:

$$\Delta_m X_{ijkt} = \beta \Delta_m h_{ijkt} + f_{ikt} + f_{jkt} + f_{ijt} + f_{ijk} + \varepsilon_{ijkt}, \tag{21}$$

where Δ_m indicates differencing the dataset by m years. The reasons for multi-year differencing are twofold. When differencing the data by several years, the reference year in the control and treatment group is shifted back in the past. As a consequence, the regression set-up is picking up some of the longer-run effects and is also safeguarding against anticipation effects (if any effect of standard harmonization is already present in the year before the actual release, differencing by several years makes the result more robust to such an anticipation effect).

Table 3: Regression results / Multi-year differences

	(1) Δ_{t-1} Total	(2) Δ_{t-2} Total	(3) Δ_{t-3} Total	(4) Δ_{t-4} Total	(5) Δ_{t-5} Total
Harmonization	-0.00132	0.00301*	0.00630***	0.00573***	0.00568***
	[0.533]	[0.094]	[0.000]	[0.001]	[0.001]
Exporter-product-time FE	yes	yes	yes	yes	yes
Importer-product-time FE	yes	yes	yes	yes	yes
Exporter-importer-time FE	yes	yes	yes	yes	yes
Exporter-importer-product FE	yes	yes	yes	yes	yes
Observations	5017031	4676493	4370967	4078732	3794623
R^2	0.22	0.25	0.27	0.30	0.32
Adjusted R^2	0.08	0.11	0.13	0.16	0.19

Notes: Regression of the log of the value of bilateral exports on harmonization indicator. Regression model corresponds to the differenced version of the baseline model (regression specification 21). Standard errors are clustered at the product-level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

The results are presented in Table 3 for one-, two-, three-, four- and five-year differences. While the one-year and two-year differences hardly show any significant results, differencing over three to five years shows the same results as the baseline regression, i.e. standard harmonization leads to a significant increase in the trade flow suggesting that the effect of standard harmonization needs time to develop. The coefficients in column (1) of the various specifications are consistent with this interpretation. After one year, the estimate on the growth rate of total trade flows is not statistically significant from zero. After two years, the effect increases to 0.3% and remains significant at around 0.6% after three, four and five years. Note that the fact that standard harmonization is only significant in the regression with multi-year differences is compatible with the results from the baseline difference-in-difference set-up (Table 2), where the dummy variable h_{ijkt} takes on the value of one at the time of the harmonized standard release and for the following years (until the next harmonization event), thus also measuring long-run effects.

6.2 Pre-trends

Another identification concern is that our difference-in-difference estimator picks up different pre-trends between harmonized and non-harmonized products. Different pre-trends arise if harmonization primarily happens in product categories where trade flows are large or when firms anticipate future standardization efforts and thus react prior to the actual harmonization event. Given that we have multiple harmonization events within an exporter-importer-product triplet, we focus only on observations that did not have any standard harmonization four years prior to the first harmonization event.[26] The regression specification with pre-trends looks as follows:

$$\log(X_{ijkt}) = \beta_h h_{ijkt} + \sum_{n=1}^{4} \beta_n d_{ijkt-n}^{1st} + f_{ikt} + f_{jkt} + f_{ijt} + f_{ijk} + \varepsilon_{ijkt}, \tag{22}$$

where the variable d_{ijkt-n}^{1st} represents a dummy that is equal to one n years prior to the first harmonization event.

Table 4: Regression results / Controlling for pre-trends

	(1) Total
Harmonization	0.00791***
	[0.000]
Harmonization (t-1)	-0.00319
	[0.510]
Harmonization (t-2)	-0.00665
	[0.232]
Harmonization (t-3)	-0.00458
	[0.457]
Harmonization (t-4)	0.00061
	[0.926]
Exporter-product-time FE	yes
Importer-product-time FE	yes
Exporter-importer-product FE	yes
Exporter-importer-time FE	yes
Observations	4580633
R^2	0.89
Adjusted R^2	0.85

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator and dummy variables for the first harmonization event shifted in time. Standard errors are clustered at the exporter-product-level. Fixed effects are included as described in the regression specification 22. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

Results are displayed in Table 4. The magnitude of the coefficient for harmonization events implies an increase of 0.79% and is comparable to the baseline specification. The pre-trend dummies are not significant for any of the four years prior to the harmonization event.

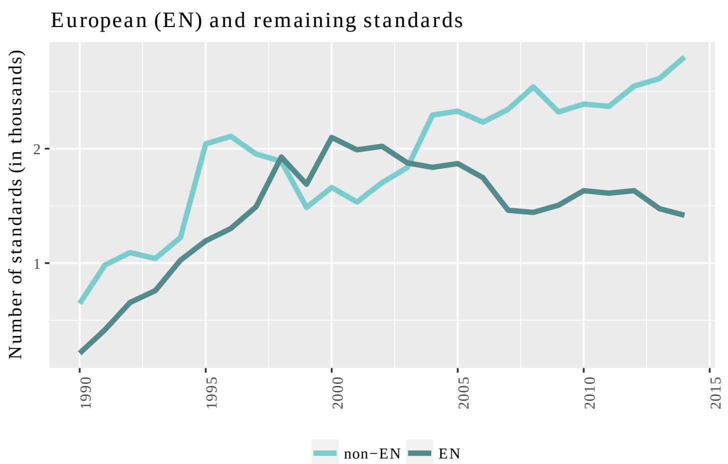
[26] Since our sample starts in 1995, we do not consider any observations that experience a harmonization event prior to the year 2000.

6.3 Endogeneity and European Standards (EN)

One of the major endogeneity concerns is that large firms lobby SSOs to accredit product standards that are favorable to them. In general, SSOs elaborate standards in working groups and technical committees that are composed of industry experts, which participate on behalf of private firms as well as governmental and non-governmental organization. While this mechanism allows private firms to influence the development and potential accreditation of a standard, their influence is limited by the voting power of other technical experts. Spulber (2019) shows that voting power and market power may have counterbalancing effects in reaching consensus that is needed in order to issue a standard. An additional limiting factor is that the firm needs to persuade all participating SSOs, foreign and national, in agreeing on the same standard.

While the voting mechanism reduces the endogeneity problem, we address remaining concerns by taking advantage of so-called European standards that have a supranational character. Once a standard is qualified as a European Standard (identified through the reference code containing the letters "EN"), it "carries with it the obligation to be implemented at national level by being given the status of a national standard and by withdrawal of any conflicting national standard" (CEN-CENELEC Internal Regulations[27]). The European Commission actively supports the development of European Standards. Figure 4 displays the number of original releases of all harmonized standards, broken down by their categorization as a European Standard (EN) or another standard. As is obvious from Figure 4, European standardization efforts picked up over the 1990s and even outnumbered other standards to a considerable extent.

Figure 4: European Standards, 1990–2014



Notes: The figure displays the number of original standard releases of all harmonized standards, broken down by the year of their original release as well as whether they constitute a European Standard or not.

The supranational character of these European standards mitigates endogeneity concerns for two reasons. First, the influence of national firms is limited and non-European

[27]See https://www.cenelec.eu/standardsdevelopment/ourproducts/europeanstandards.html.

countries also accredit European Standards (EN), which makes it harder for European firms to lobby for the accreditation of a standard. Second, the timing of the accreditation of European Standards by national SSOs varies across countries. The majority of these accreditations take place with a lag of one or more years after the original release. The introduced uncertainty about the timing is important as the definition of the harmonization dummy relies on the year the national SSO accredits the standard and not on the time the EN standard was issued.

We run the same regression model as before, but limit the construction of the harmonization indicator to European standards. The results are displayed in Table 5. The results are quantitatively and qualitatively very similar to the baseline specification: using European Standards implies an increase of trade flows of 0.53% following a harmonization event.

Table 5: Regression results / European Standards

	(1) Total
Harmonization	0.00528*** [0.009]
Exporter-product-time FE	yes
Importer-product-time FE	yes
Exporter-importer-product FE	yes
Exporter-importer-time FE	yes
Observations	6194987
R^2	0.88
Adjusted R^2	0.85

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator that only takes into consideration EN standards. Fixed effects are included as described in the regression specification 17. Standard errors are clustered at the exporter-product-level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

6.4 IV regressions

We resort to instrumental variable techniques to further analyze to what extent our results are robust to the possibility that the accreditation of standards is subject to firm lobbying. A commonly used instrument for specific public policies are policies conducted by neighboring countries (see, for example, Buera et al., 2011; Giuliano et al., 2013 and Kee and Nicita, 2016 in the specific context of trade policies). The underlying idea is that trade policies of neighboring countries, due to similarities in terms of economic structure or geographic characteristics, are a good predictor of a country's own policies, but are not the target of lobbying efforts by domestic firms. Using CEPII's GeoDist database (Mayer and Zignago, 2011), we identify an exporting country's neighbors among the countries in our database and calculate the mean number of harmonization events with respect to each importing country. If this average is larger than or equal to 0.5, we code it as a harmonization event ($h_{ijkt}^{IV} = 1$).We consider a country to be a neighbor if it shares a common language or a land border with another country.[28] To address the concern that the results are driven by European countries and their common trade policies, we conduct the analysis for the full sample and a reduced sample without European countries.

The results using the full sample are displayed in columns (1) and (2) of Table 6, while the results for the sample consisting of non-European countries are shown in columns (3) and (4). Column (1) and column (3) display the results of the first stage: the mean number of harmonized standard releases of neighboring countries constitute a relevant predictor of a country's own harmonization events and the F-statistic dismisses the possibility that the IV estimates are biased due to weak instruments. The second-stage results, displayed in columns (2) and (4), show that overall trade increases significantly in both samples, which is in line with our baseline estimates.

Table 6: Regression results / Instrumental variables

	All countries		Non-EU countries	
	1st stage (1)	2nd stage (2)	1st stage (3)	2nd stage (4)
Harmonization neighbors	0.23846***		0.12188***	
	[0.000]		[0.000]	
Harmonization		0.01861**		0.04344*
		[0.013]		[0.075]
Exporter-product-time FE	yes	yes	yes	yes
Importer-product-time FE	yes	yes	yes	yes
Exporter-importer-product FE	yes	yes	yes	yes
Exporter-importer-time FE	yes	yes	yes	yes
Observations	5848855	5848855	938639	938639
F-statistic	3811		612	

Notes: Instrumental variables regression of the respective dependent variable (designated in column headers) on harmonization indicator where harmonization is instrumented by neighbors' harmonization. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

In terms of economic magnitudes, the IV estimates are larger than the OLS ones. However, the Durbin-Wu-Hausman test shows that we cannot reject the null hypothesis of the OLS estimator yielding consistent estimates; we thus conclude that there are no statistically significant differences between the OLS and IV estimates. Under the assumption that our instrument is indeed exogenous and given that the OLS estimator is more efficient, we consider OLS our preferred estimation method.

6.5 Additional robustness

We briefly summarize additional robustness checks reported in Appendix E below. First, we include a flexible difference-in-difference specification that allows for a non-constant marginal effect that varies with treatment intensity. The results show the marginal effect of

[28] A certain number of countries do not share a language or border with any of the rest of the countries in our database: Brazil, Japan, Jordan, South Korea and Turkey. For Japan and South Korea, we consider the countries with which they share a maritime border as neighbors. For Brazil, Jordan and Turkey, we define the three closest countries in our database as neighbors.

harmonization events is linear in the number of harmonization events (up to 12-13 events). For a higher number of harmonization events, the marginal effect remains positive but confidence intervals increase significantly. Second, we estimate our baseline specification using our concordance table obtained via keyword-matching techniques. The results are comparable to the baseline estimates reported in Table 2. Third, we address the problem of zeros in the gravity equation and estimate the baseline specification using the PPML approach advocated by Silva and Tenreyro (2006). The estimated effects for standard harmonization remain positive and significant, although the coefficient decreases in magnitude.

Overall, the evidence presented in this section suggests that our results are robust to endogeneity concerns and model specification. We can exclude that the results are driven by the size effect of large trade flows. Including pre-trends into the analysis shows that these are not significant. Finally, addressing potential endogeneity bias with IV techniques and using a measure of largely exogenous, supranational standards yields results that are consistent with the baseline approach.

7 Evidence on empirical implications of the model

According to our theoretical model, harmonized product standards allow for cost complementarities across markets and induce firms to produce in accordance with the standard. The data do not allow us to identify the firms that adopt a product standard and the firms that do not. To lend support to the proposed mechanism of the model, this section provides empirical evidence that is consistent with the model's predictions on firm- and product-level trade flows after a standard harmonization event. The first exercise takes advantage of French firm-level data and provides evidence consistent with the model's implied selection effect, where only large exporters choose to produce in accordance with the standard. Second, we investigate whether harmonized standards generate consumer demand by exploiting product characteristics that are indicative of stronger demand effects. The third exercise evaluates the heterogeneous effects of standard harmonization due to trade costs as well as destination and home market characteristics. Finally, we analyze the impact of national standards on international trade flows.

7.1 Firm-level evidence

According to equation 14 of the model, the presence of sunk investment costs implies that only very productive (large) firms will opt to invest into the product standard. To shed light on these predictions, we decompose French bilateral product-level trade flows in equation 15 into an extensive and intensive margin. Following Buono and Lalanne (2012), we write the intensive margin as the average firm-level sales per HS 4-digit product ($\bar{x}_{ijkt} = X_{ijkt}/M_{ijkt}$) and the extensive margin as the number of firms exporting (M_{ijkt}) within the HS 4-digit sector. Given these definitions and taking the log, the decomposition equals

$$\log(X_{ijkt}) = \log(M_{ijkt}) + \log(\bar{x}_{ijkt}). \tag{23}$$

We match our standard harmonization database at the HS 4-digit level with French firm-level data obtained from French custom declarations for the period 1995–2014. We have information on the euro value of exports by each firm and restrict the sample to the 25 importing countries in our standard database. Column (1) in Table 7 shows that standard harmonization increases French exports by 1.7%, which is slightly higher than in our baseline product-level regression in Table 2. The decomposition shows that standard harmonization allows exporters to expand their sales (positive effect on the intensive margin) and there is no significant effect on entry.

Table 7: Regression results: Gravity equation

	(1) Total	(2) Extensive Margin	(3) Intensive Margin
Harmonization	0.01740***	0.00319	0.01422***
	[0.005]	[0.108]	[0.010]
Product-time FE	yes	yes	yes
Importer-product FE	yes	yes	yes
Importer-time FE	yes	yes	yes
Observations	300457	300457	300457
R^2	0.88	0.97	0.80
Adjusted R^2	0.87	0.96	0.78

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Standard errors are clustered at the 4-digit HS level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

To provide further supportive evidence for these results, we bring our analysis to the firm-level and estimate the following regression specification

$$Y_{fjnt} = \beta h_{jnt} + f_{fjn} + f_{fjt} + \varepsilon_{fjnt}, \tag{24}$$

where f designates a firm, n the HS 6-digit product-level, j the importing country and t the year of observation. We measure the extensive margin ("export status") by specifying a dummy variable Y_{fjnt} that equals one if the firm has positive exports and zero otherwise. The second variable consists of total export sales per firm f in an HS 6-digit category n to importing country j in year t (in logs), which we further decompose into prices (proxied by unit values in terms of kilograms shipped) and quantities; both variables are included in logs. Equation 24 includes fixed effects on the firm-importer-product-level (f_{fjn}) as well as the firm-importer-year level (f_{fjt}).[29]

The results shown in Table 8 are similar to the results obtained from the gravity decomposition (see Table 7). Standard harmonization is associated with an increase of total sales (column (2)) by 0.69% and by 0.59% when focusing on the sample of firms for which we have unit value and quantity data (column (3)). Concerning the extensive margin, we find no evidence of new entry, see column (1). Column (4) and column (5) split

[29]We also ran our firm-level regressions with a less demanding fixed-effects set-up as in Fontagné et al. (2015) by including HS2-destination-year ($f_{HS2,j,t}$) and firm (f_f) fixed effects. In this case, all coefficients for export status, total sales as well as prices and quantities are positive and significant.

Table 8: Regression results: Firm-level data

	(1) Export status	(2) Sales	(3) Sales	(4) Price	(5) Quantity
Harmonization	0.00084	0.00691***	0.00586***	0.00188*	0.00398**
	[0.185]	[0.000]	[0.002]	[0.080]	[0.044]
Firm-importer-year FE	yes	yes	yes	yes	yes
Firm-importer-product FE	yes	yes	yes	yes	yes
Observations	12634460	5285380	4506939	4506939	4506939
R^2	0.63	0.85	0.86	0.94	0.90
Adjusted R^2	0.55	0.80	0.80	0.91	0.86

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Columns (3)–(5) are based on a regression sample containing only observations for which information on quantities is available. Fixed effects are included as described in the regression specification 24. Standard errors are clustered at the HS6 level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

the log of firm sales into the log price (unit values) and the log quantity component. Table 8 shows that firms sell larger volumes despite charging higher prices. These results favor the interpretation that standard harmonization increases product demand as predicted by the model. We do not find much evidence that harmonized standards reduce variable costs, which should result in lower prices.

The key implication of our model is that harmonization generates a selection effect, which incentives large firms to invest into the product standard and to increase their sales. We investigate the model implication that the positive effect of standard harmonized should vary with the exporters' size distribution using quartile-based bins as in Lileeva and Trefler (2010). To construct the bins, we sum export sales across all markets and products for each firm and calculate the size quartiles from the resulting sales distribution. We then group each firm into one of the four bins and estimate the effect of harmonization for each size quartile separately.[30] Table 9 panel(a) shows that the positive effects of harmonized standard releases are entirely driven by the largest firms in the forth quartile for which trade flows increase by 1.2%. For all other quartiles, the effect is not significant.

[30] An alternative specification with interaction terms of the harmonization dummy and each size bin dummy leads to the same results. Results based on ten bins rather than four size bins show that only firms in the top 3 bins experience higher sales.

Table 9: Firm-level data for size quartiles and destination characteristics

(a) Dependent variable: log(*sales*)

	(1) 1st quartile	(2) 2nd quartile	(3) 3rd quartile	(4) 4th quartile
Harmonization	-0.00130	0.00786	0.00176	0.01213**
	[0.846]	[0.272]	[0.773]	[0.035]
Firm-importer-year FE	yes	yes	yes	yes
Firm-importer-product FE	yes	yes	yes	yes
Observations	762640	1233791	1477145	1655427
R^2	0.85	0.85	0.86	0.85
Adjusted R^2	0.73	0.76	0.79	0.81

(b) Dependent variable: log(*sales*)

	(1) 1st quartile	(2) 2nd quartile	(3) 3rd quartile	(4) 4th quartile
Harmonization	0.00000	0.00330	0.00158	0.01077*
	[1.000]	[0.607]	[0.805]	[0.070]
Harmonization x Dest. market size	0.00001	0.00003	0.00013***	0.00022***
	[0.675]	[0.395]	[0.001]	[0.003]
Harmonization x log(distance)	-0.00012	0.00005	0.00002	-0.00022**
	[0.549]	[0.732]	[0.872]	[0.040]
Firm-importer-year FE	yes	yes	yes	yes
Firm-importer-product FE	yes	yes	yes	yes
Observations	762640	1233791	1477145	1655427
R^2	0.84	0.85	0.86	0.85
Adjusted R^2	0.73	0.77	0.80	0.81

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Columns (1)–(4) represent the exporter-size quantile calculated by considering the distribution of total firm export sales for each year. All regressions include time-varying firm specific importer fixed effects and time-varying firm specific product fixed effects. Standard errors are clustered at the HS6 level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

As equation 14 shows, a larger destination market should amplify the trade-enhancing effects of harmonized standard releases on large firms. Similarly, low trade costs amplify these effects. In Table 9 panel(b), we interact the harmonization dummy with the log of nominal GDP in the destination country in the year 1995 (proxy for destination market size) as well as with the log of the bilateral distance between France and the destination country (to proxy for trade costs).[31] The results show that the positive effect for the forth quartile increases in destination market size and decreases with distance. Harmonization also increases export sales of firms in the third quartile but only in large destination markets. For other firms, the results are insignificant.

The firm-level results also inform on the regulatory nature of the product standards in our database. If standards are legally binding, all firms have to produce the product attributes prescribed by the standard and pay the sunk investment costs. This type of cost weighs more heavily on smaller firms and should affect them the most, either on the entry margin or through relative larger changes in export sales compared with large firms.[32] As

[31]Given that we do not observe domestic sales in France, we cannot test for the importance of home market size for standard harmonization.

[32]In models with regulatory standards (such as Mei, 2017 or Macedoni and Weinberger, 2018), z_k defines a

the results in Tables 8 and 9 show, we do not find empirical support for these predictions. Overall, our firm-level evidence supports the assumptions and the predictions of the model by showing that (1) standard harmonization primarily benefits large exporters and (2) the positive effects increase with proximity and size of the destination market. These firms are able to expand their sales by selling more quantities at higher prices.

7.2 Evidence on demand-shifting

In the theoretical framework, we argue that the main channel through which standardization materializes into larger trade flows is the creation of higher consumer demand. In terms of horizontal differentiation, standards allow for network effects and interoperability and reduce information asymmetries; the use of a common standard renders extensive product descriptions obsolete, as producers can simply refer to the standard to convince importers of the properties of their product. The resulting demand effects are captured by a shift in demand (respectively z_{jk} or z_k) towards these standardized varieties. In terms of vertical differentiation, standards reduce information asymmetries and allow consumers to infer the quality of a product via certification and labeling: it is easier for producers of high-quality goods to market their products.

Our database contains standards addressing issues of horizontal and vertical differentiation and we do not take a stance on their respective prevalence, keeping in mind that standards often fulfill several purposes at once. However, we can test whether the proposed demand-shifting is stronger for differentiated products, horizontally or vertically. To proxy for horizontal differentiation, we use the classification by Rauch (1999), which categorizes products as either being differentiated or homogeneous.[33] Network effects and interoperability are typically associated with technology-intensive and manufactured goods rather than commodities (see the discussion in Gandal, 2002) which is why we expect differentiated product categories to react more strongly to harmonized standard releases. The same argument applies to the reduction of information asymmetries for complex products.

For vertically differentiated products, we use the "quality ladder" index from Khandelwal (2010). The "quality ladder" index measures the range of qualities within a product category and is defined as the difference between the highest and lowest quality level. As Khandelwal (2010) shows, a higher index is associated with a higher degree of differentiation. Thus, we expect that the positive effects of standard harmonization increases more in product categories with more scope for quality differentiation (longer quality ladders).

We interact these indicators with our harmonization indicator and follow the baseline regression set-up:

$$\log X_{ijk} = \beta_0 h_{ijkt} + \beta_1 h_{ijkt}\text{Rauch}_k + \beta_2 h_{ijkt}\text{Qladder}_k + f_{ijk} + f_{ikt} + f_{jkt} + f_{ijt} + e_{ijkt}$$

minimal level of product attribute that firms have to produce. In this version of our model the marginal exporter would experience the largest sales gains from complementarities in sunk investment costs.

[33] Rauch (1999) distinguishes between products traded on organized exchanges or products that have a reference price. In our exercise, we summarize these categories in one.

where Rauch_k is a dummy indicator that takes the value of one if product k is a differentiated product as defined by Rauch (1999) and Qladder_k is a dummy indicator that equals one for a product k if the product-specific quality ladder index from Khandelwal (2010) is above the median index.[34]

Table 10: Regression results: differentiated products

	(1) Total	(2) Total	(3) Total
Harmonization	0.00157	0.00167	-0.00043
	[0.488]	[0.405]	[0.850]
Harmonization x Rauch index	0.01692***		0.01399***
	[0.000]		[0.000]
Harmonization x Quality ladder		0.02168***	0.01487***
		[0.000]	[0.001]
Exporter-product-time FE	yes	yes	yes
Importer-product-time FE	yes	yes	yes
Exporter-importer-product FE	yes	yes	yes
Exporter-importer-time FE	yes	yes	yes
Observations	5176560	5848855	5176560
R^2	0.88	0.88	0.88
Adjusted R^2	0.85	0.85	0.85

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Standard errors are clustered at the HS4 level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

Column (1) in Table 10 shows that the effect of harmonized standard releases is mainly present in horizontally differentiated products. The positive coefficient for the Rauch dummy implies that standard harmonization increases international trade for differentiated products by 1.6%, while the insignificant effect for the harmonization variable suggests no effect for homogeneous products. We consider these results as suggestive evidence that demand shifts through an increase of compatibility or a reduction of information asymmetries. This interpretation is similar to Rauch (1999) or more recently Brynjolfsson et al. (2018), who show that a reduction in search costs, as in the case of language barriers, increases trade flows, and that this effect is even more pronounced for differentiated products.

Column (2) in Table 10 shows that the effect of standard harmonization is also larger in product categories that allow for more vertical differentiation. For example, trade flows in product categories with a quality ladder length above the median see a rise of 2.1% in international trade. We therefore conclude that standards enable greater transparency about the quality of a product which, in turn, encourages firms to produce high-quality products (Armstrong and Chen, 2009) or facilitates the marketing of products that are already characterized by high quality, but whose consumers are unaware of the quality in the absence of a standard.

[34] In an alternative specification, we use the product-specific quality ladder index rather than a dummy variable and experimented with using the elasticity of substitution estimates from Soderbery (2018) as proxy a for horizontal differentiation. Both modifications lead to similar results.

7.3 Heterogeneous effects of standard harmonization on the product-level

The third exercise exploits the model's implied heterogeneous effects of standard harmonization at the product-level. Equations 15 and 16 show that the magnitude of the positive effect of standard harmonization on trade flows depends on the market size of the exporting country, the market size of the importing country and the trade costs between the harmonizing countries.

The presence of sunk investment costs implies that market size matters for the decision to produce in accordance with a product standard because firms can exploit scale effects. As the cut-off expression in equation 14 shows, the number of firms that decide to produce the standardized variety increases in home as well as in destination market size. However, at the product-level, the marginal effect of standard harmonization does not depend on the absolute number but on the share of firms that decide to produce the standardized variety, see equation 16. Given that a larger destination market also attracts more firms exporting the non-standardized variety and this effect dominates, the share of exporters that produce according to the standard should be smaller in larger destination markets and lower the positive effect of standard harmonization. Or, put differently, exports to small countries rise more than those to large countries following the release of a harmonized standard. The reason is that the home market size and the associated cost complementarities are more important in smaller destination markets, which implies that a larger share of firms decide to export the standardized variety.

The last factor we consider are trade costs, which we proxy by distance. Lower trade costs between the countries harmonizing a product standard increase the incentives for firms to produce the standardized variety and magnify the positive effect of standard harmonization, see the firm-level results in Table 9. However, at the product-level, the same compositional effect as in the case of destination market size is at play and the number of firms producing the non-standardized variety increases to a larger extent with lower trade costs. This implies a magnified effect of standard harmonization in more distant markets because they feature a larger share of firms that export the product standard.

We interact the harmonization dummy with destination market size ($\log(GDP_{j,1995})$) in the year 1995 (the first year of our sample period), home market size ($\log(GDP_{i,1995})$) in the year 1995, and log of distance between exporter i and importer j ($\log(d_{ij})$). The regression specification follows once again the baseline set-up:

$$\begin{aligned}\log X_{ijk} =&\beta_0 h_{ijkt} + \beta_1 h_{ijkt}\log(GDP_{j,1995}) + \beta_2 h_{ijkt}\log(GDP_{i,1995}) + \beta_3 h_{ijkt}\log(d_{ij})\\ &+ f_{ijk} + f_{ikt} + f_{jkt} + f_{ijt} + e_{ijkt}\end{aligned}$$

Given our model, we expect $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 > 0$.

The results are summarized in Table 11. We observe that the effect of standard harmonization increases with home market size, while it decreases with destination market size and distance as predicted by the model in Section 3. In relative terms, the fixed investment costs are more important for smaller markets. As the release of harmonized standards allows for cost complementarities which incentivize the adoption of a standard, the releative effect is larger in smaller destination markets. The same argument applies to bilateral trade costs.

Table 11: Regression results: heterogeneous product-level results

	(1) Total	(2) Total	(3) Total	(4) Total
Harmonization	0.00949***	0.00868***	0.00674***	0.00606***
	[0.000]	[0.000]	[0.000]	[0.000]
Harmonization x Dest. market size	-0.01827***	-0.02108***	-0.10275***	-0.10469***
	[0.000]	[0.000]	[0.000]	[0.000]
Harmonization x Home market size		0.00779**		0.00664*
		[0.033]		[0.069]
Harmonization x log(distance)			0.00390***	0.00388***
			[0.000]	[0.000]
Exporter-product-time FE	yes	yes	yes	yes
Importer-product-time FE	yes	yes	yes	yes
Exporter-importer-product FE	yes	yes	yes	yes
Exporter-importer-time FE	yes	yes	yes	yes
Observations	5848855	5848855	5848855	5848855
R^2	0.88	0.88	0.88	0.88
Adjusted R^2	0.85	0.85	0.85	0.85

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Standard errors are clustered at the HS4 level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

7.4 National standards

Our theoretical model implies that the release of national standards can also increase bilateral trade as some exporters may find it worthwhile to produce in accordance with the foreign standard (if such a standard is in place). The positive effect of national standards on bilateral trade can be larger than in the case of harmonized standards if national standards can be geared towards domestic preferences for product attributes and lead to positive demand effects that more than compensate for the cost complementarities due to harmonized standards. To shed light on the channel, we include dummy variables for the release of national standards by the importing country n_{jkt}:

$$\log X_{ijk} = \beta_0 h_{ijkt} + \beta_1 n_{jkt} + f_{ikt} + f_{ijk} + f_{ijt} + e_{ijkt}.$$

The results in Table 12 show the estimated effect of national standards on bilateral trade flows together with a comparison of harmonized product standards. Once we control for supply side effects with time-varying product-specific exporter fixed, the positive effect of national standards in column (1) becomes insignificant (see column (2) and (3)), while the positive effect for harmonized standards remains. These results suggest that positive demand effects from national standards are not significant to stimulate investment into the national standard, while cost complimentarities induce firms to invest into the harmonized standards and increase trade. We consider this as supportive for our model.

We also note that the non-significant coefficient for national standards has implications on the regulatory nature of the standards in our database. If these were largely regulatory instead of voluntary, we should observe a negative effect as it is the case in papers using a similar identification strategy but focusing on regulatory standards (e.g. Fontagné et al., 2015 and Fernandes et al., 2019). An important drawback of the estimation strategy in equation 25 is that we cannot control for time-varying product-specific characteristics in the destination market that are potentially correlated with the release of national standards (for example, larger markets may have a higher incentive to issue national standards compared to smaller countries).

Table 12: Regression results: national standards

	(1) Total	(2) Total	(3) Total
National foreign	0.02358***	-0.00099	-0.00164
	[0.000]	[0.445]	[0.210]
Harmonization			0.00759***
			[0.000]
Exporter-product-time FE	no	yes	yes
Importer-product-time FE	no	no	no
Exporter-importer-product FE	yes	yes	yes
Exporter-importer-time FE	yes	yes	yes
Observations	5885597	5861583	5861583
R^2	0.83	0.86	0.86
Adjusted R^2	0.82	0.84	0.84

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Standard errors are clustered at the HS4 level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

8 Conclusion

Data limitations have prevented a thorough analysis of the economic effects of standardization and cross-border harmonization efforts. This paper is a first attempt to fill this gap by providing a novel database that tracks national and international product standards and quantifies their impact on international trade. Our results show that standard harmonization has a significant positive impact on global trade that is twice as large as the effect of tariff reductions. The magnitude of this effect is largely driven by the widespread use of standards. During our sample period of 1995 to 2014, every year more than 40% of bilateral product-level trade flows were subject to standard harmonization.

Product standards affect trade flows differently from tariffs. The evidence in this paper suggests that standards increase trade by providing incentives for firms to upgrade their products. In our framework, product standards describe attributes such as compatibility, reliability and quality that generate consumers demand. To benefit from the higher demand, firms need to incur a sunk investment costs. Harmonized standards reduce these costs by allowing for cost complementarities across countries and stimulate investment into the product attributes prescribed by the standard. Harmonizing product standards across countries can be an effective policy tool in facilitating common product specifications across countries and foster trade integration.

While our results show that harmonized standard releases have a positive impact on trade flows, important questions remain with respect to the optimality of the standard-setting process, but which are beyond the reach of this paper. If firms profit disproportionally from the standard-setting process, i.e. when SSOs standardize a patented technology (see, for example, Schmalensee, 2009, Llanes and Poblete, 2014 and Lerner and Tirole, 2015), issues with respect to the competitive structure of the market arise. The fact that predominantly large firms benefit from standard harmonization hints in this direction. More generally, standardization can be harmful to innovation and long-term growth when an industry becomes “locked in” a certain technology (QWERTY is a famous example, see David, 1985, and Farrell and Saloner, 1985, 1986 for further evidence). In this paper, we quantify the aggregate effect of harmonized standardization activity across the universe of technical and product standards and abstract from standard-specific mechanisms. Exploiting the heterogeneous effects of standards as well as their development and accreditation are important avenues for future research.

References

Amiti, Mary and Amit K. Khandelwal (2013): Import Competition and Quality Upgrading. *The Review of Economics and Statistics*, 95(2), pp. 476–490.

Arkolakis, Costas, Sharat Ganapati and Marc-Andreas Muendler (2016): The Extensive Margin of Exporting Products: A Firm-level Analysis. Cowles Foundation Discussion Papers 2028, Cowles Foundation for Research in Economics, Yale University.

Armstrong, Mark and Yongmin Chen (2009): Inattentive Consumers and Product Quality. *Journal of the European Economic Association*, 7(2-3), pp. 411–422.

Atkeson, Andrew, Christian Hellwig and Guillermo Ordoñez (2014): Optimal regulation in the presence of reputation concerns. *The Quarterly Journal of Economics*, 130(1), pp. 415–464.

Baier, Scott L., Jeffrey H. Bergstrand and Michael Feng (2014): Economic integration agreements and the margins of international trade. *Journal of International Economics*, 93(3), pp. 339–350.

Baldwin, Richard E (2011): 21st Century Regionalism: Filling the gap between 21st century trade and 20th century trade rules. *Available at SSRN 1869845*.

Baldwin, Richard E., John McLaren and Arvind Panagariya (2000): Regulatory protectionism, developing nations, and a two-tier world trade system. In: *Brookings Trade Forum*, pp. 237–293. JSTOR.

Baron, Justus and Daniel F. Spulber (2018): Technology standards and standard setting organizations: Introduction to the Searle Center Database. *Journal of Economics & Management Strategy*, 27(3), pp. 462–503.

Bas, Maria and Vanessa Strauss-Kahn (2015): Input-trade liberalization, export prices and quality upgrading. *Journal of International Economics*, 95(2), pp. 250–262.

Berman, Nicolas, Vincent Rebeyrol and Vincent Vicard (2019): Demand Learning and Firm Dynamics: Evidence from Exporters. *The Review of Economics and Statistics*, 101(1), pp. 91–106.

Blind, Knut (2004): *The Economics of Standards: Theory, Evidence, Policy*. Edward Elgar Publishing Ltd.

Brynjolfsson, Erik, Xiang Hui and Meng Liu (2018): Does Machine Translation Affect International Trade? Evidence from a Large Digital Platform. Working Paper 24917, National Bureau of Economic Research.

Buera, Francisco J, Alexander Monge-Naranjo and Giorgio E Primiceri (2011): Learning the wealth of nations. *Econometrica*, 79(1), pp. 1–45.

Buono, Ines and Guy Lalanne (2012): The effect of the Uruguay Round on the intensive and extensive margins of trade. *Journal of International Economics*, 86(2), pp. 269–283.

Bustos, Paula (2011): Trade liberalization, exports, and technology upgrading: Evidence on the impact of MERCOSUR on Argentinian firms. *American economic review*, 101(1), pp. 304–40.

Chaney, T. (2008): Distorted gravity: The intensive and extensive margins of international trade. *The American Economic Review*, 98(4), pp. 1707–1721.

Chen, Maggie Xiaoyang and Aaditya Mattoo (2008): Regionalism in standards: Good or bad for trade? *Canadian Journal of Economics*, 41(3), pp. 838–863.

Chen, Natalie and Dennis Novy (2012): On the measurement of trade costs: direct vs. indirect approaches to quantifying standards and technical regulations. *World Trade Review*, 11(3), pp. 401–414.

Costinot, Arnaud (2008): A comparative institutional analysis of agreements on product standards. *Journal of International Economics*, 75(1), pp. 197–213.

David, Paul A (1985): Clio and the Economics of QWERTY. *The American economic review*, 75(2), pp. 332–337.

Disdier, Anne-Célia, Lionel Fontagné and Olivier Cadot (2015): North-South standards harmonization and international trade. *World Bank Economic Review*, 29(2), pp. 327–352.

Ederington, J. and M. Ruta (2016): Nontariff Measures and the World Trading System. *Handbook of Commercial Policy*, vol. 1, pp. 211–277. North-Holland.

Fan, Haichao, Yao Amber Li and Stephen R. Yeaple (2015): Trade Liberalization, Quality, and Export Prices. *The Review of Economics and Statistics*, 97(5), pp. 1033–1051.

Farrell, Joseph and Paul Klemperer (2007): Coordination and lock-in: Competition with switching costs and network effects. *Handbook of Industrial Organization*, 3, pp. 1967–2072.

Farrell, Joseph and Garth Saloner (1986): Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation. *The American Economic Review*, 76(5), pp. 940–955.

Farrell, Joseph von R. and Garth Saloner (1985): Standardization, compatibility, and innovation. *The RAND Journal of Economics*, 16(1), pp. 70–83.

Fernandes, Ana M., Esteban Ferro and John S. Wilson (2019): Product standards and firms' export decisions. *The World Bank Economic Review*, 33(2), pp. 353–374.

Fischer, Ronald and Pablo Serra (2000): Standards and protection. *Journal of International Economics*, 52(2), pp. 377–400.

Fontagné, Lionel, Gianluca Orefice, Roberta Piermartini and Nadia Rocha (2015): Product standards and margins of trade: Firm-level evidence. *Journal of International Economics*, 97(1), pp. 29–44.

Gandal, Neil (2002): Compatibility, standardization, and network effects: Some policy implications. *Oxford Review of Economic Policy*, 18(1), pp. 80–91.

Gandal, Neil and Oz Shy (2001): Standardization policy and international trade. *Journal of International Economics*, 53(2), pp. 363–383.

Ganslandt, Mattias and James R. Markusen (2001): Standards and Related Regulations in International Trade: A Modeling Approach. NBER Working Papers 8346, National Bureau of Economic Research, Inc.

Gaulier, Guillaume and Soledad Zignago (2010): BACI: International Trade Database at the Product-Level. The 1994-2007 Version. *CEPII Working Paper*, 2010-23.

Giuliano, Paola, Prachi Mishra and Antonio Spilimbergo (2013): Democracy and reforms: evidence from a new dataset. *American Economic Journal: Macroeconomics*, 5(4), pp. 179–204.

Goldberg, Pinelopi K. and Nina Pavcnik (2016): The Effects of Trade Policy. *Handbook of Commercial Policy*, vol. 1, pp. 161–206. North-Holland.

Grossman, Gene M, Phillip McCalman and Robert W Staiger (2019): The ”New” Economics of Trade Agreements: From Trade Liberalization to Regulatory Convergence? Tech. rep., National Bureau of Economic Research.

Han, Xinfen, Julia Schmidt and Walter Steingress (2019): Constructing a Concordance Table between HS and ICS. Mimeo.

Head, Keith and Thierry Mayer (2014): Chapter 3 - Gravity Equations: Workhorse,Toolkit, and Cookbook. In: Gita Gopinath, Elhanan Helpman and Kenneth Rogoff (eds.), *Handbook of International Economics*, *Handbook of International Economics*, vol. 4, pp. 131 – 195. Elsevier.

ISO (2016): Annual Report: Navigating a World in Transition. Tech. rep., International Organization for Standardization, Geneva.

Katz, Michael L. and Carl Shapiro (1985): Network externalities, competition, and compatibility. *The American Economic Review*, 75(3), pp. 424–440.

Kee, Hiau Looi and Alessandro Nicita (2016): Trade Frauds, Trade Elasticities and Non-Tariff Measures. *Mimeo.*

Kee, Hiau Looi, Alessandro Nicita and Marcelo Olarreaga (2009): Estimating trade restrictiveness indices. *The Economic Journal*, 119(534), pp. 172–199.

Khandelwal, Amit (2010): The long and short (of) quality ladders. *The Review of Economic Studies*, 77(4), pp. 1450–1476.

Kindleberger, Charles P. (1983): Standards as Public, Collective and Private Goods. *Kyklos*, 36(3), pp. 377–396.

Larch, Mario, Joschka Wanner, Yoto Yotov and Thomas Zylkin (2017): The Currency Union Effect: A PPML Re-assessment with High-Dimensional Fixed Effects. School of Economics Working Paper Series 2017-7, LeBow College of Business, Drexel University.

Leland, Hayne E (1979): Quacks, lemons, and licensing: A theory of minimum quality standards. *Journal of Political Economy*, 87(6), pp. 1328–1346.

Lerner, Josh and Jean Tirole (2015): Standard-Essential Patents. *Journal of Political Economy*, 123(3), pp. 547–586. doi:10.1086/680995.

Lileeva, Alla and Daniel Trefler (2010): Improved access to foreign markets raises plant-level productivity... for some plants. *The Quarterly journal of economics*, 125(3), pp. 1051–1099.

Llanes, Gastón and Joaquín Poblete (2014): Ex ante agreements in standard setting and patent-pool formation. *Journal of Economics & Management Strategy*, 23(1), pp. 50–67.

Macedoni, Luca and Ariel Weinberger (2018): Quality Heterogeneity and Misallocation: The Welfare Benefits of Raising Your Standards. Mimeo.

Maggi, Giovanni and Ralph Ossa (2019): Are Trade Agreements Good for You?

Maskus, Keith E., Tsunehiro Otsuki and John S. Wilson (2005): The cost of compliance with product standards for firms in developing countries: An econometric study. Policy Research Working Paper Series 3590, The World Bank.

Maur, Jean-Christophe and Ben Shepherd (2011): Product Standards. In: Jean-Pierre Chauffour and Jean-Christophe Maur (eds.), *Preferential Trade Agreement Policies for Development*, pp. 197–216. The World Bank.

Mayer, Thierry and Soledad Zignago (2011): Notes on CEPII's Distances Measures: The GeoDist Database. Working Papers 2011-25, CEPII.

McDaniels, Devin, Ana Cristina Molina and Erik N Wijkström (2018): A Closer Look At WTO's Third Pillar: How WTO Committees Influence Regional Trade Agreements. *Journal of International Economic Law*, 21(4), pp. 815–843.

Mei, Yuan (2017): Regulatory Protection and the Role of International Cooperation. Mimeo.

Melitz, M. J. (2003): The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6), pp. 1695–1725.

Moenius, Johannes (2006): The Good, the Bad and the Ambiguous: Standards and Trade in Agricultural Products. Mimeo.

Parenti, Mathieu and Gonzague Vannoorenberghe (2019): A Simple Theory of Deep Trade Integration. *Mimeo.*

Podhorsky, Andrea (2013): Certification programs and north-south trade. *Journal of Public Economics*, 108, pp. 90–104.

Rauch, James E. (1999): Networks versus markets in international trade. *Journal of International Economics*, 48(1), pp. 7–35.

Reyes, José-Daniel (2011): International Harmonization of Product Standards and Firm Heterogeneity in International Trade. Policy Research Working Paper Series 5677, The World Bank.

Rodrigue, Joel and Yong Tan (2019): Price, Product Quality, And Exporter Dynamics: Evidence From China. *International Economic Review*, 60(4), pp. 1911–1955.

Schmalensee, Richard (2009): Standard-setting, innovation specialists and competition policy. *The Journal of Industrial Economics*, 57(3), pp. 526–552.

Shepherd, Ben (2007): Product Standards, Harmonization, and Trade: Evidence from the Extensive Margin. Policy Research Working Paper Series 4390, The World Bank.

Silva, J. M. C. Santos and Silvana Tenreyro (2006): The Log of Gravity. *The Review of Economics and Statistics*, 88(4), pp. 641–658.

Soderbery, Anson (2018): Trade elasticities, heterogeneity, and optimal tariffs. *Journal of International Economics*, 114, pp. 44–62.

Spulber, Daniel F (2019): Standard setting organisations and standard essential patents: Voting and markets. *The Economic Journal*, 129(619), pp. 1477–1509.

Swann, G. M. Peter (2010): International Standards and Trade: A Review of the Empirical Literature. OECD Trade Policy Papers 97, OECD Publishing.

Swann, Peter (2000): The Economics of Standardization. Final Report for Standards and Technical Regulations Directorate Department of Trade and Industry. Tech. rep., University of Manchester, Manchester, UK.

Swann, Peter, Paul Temple and Mark Shurmer (1996): Standards and trade performance: The UK experience. *The Economic Journal*, 106(438), pp. 1297–1313.

Toulemonde, Eric (2013): A welfare analysis of the principle of mutual recognition. *European Economic Review*, 60, pp. 1–16.

Verhoogen, Eric A (2008): Trade, quality upgrading, and wage inequality in the Mexican manufacturing sector. *The Quarterly Journal of Economics*, 123(2), pp. 489–530.

A Appendix: Model

Firm profits and sales

Firms can produce a standardized or a non-standardized variety. Firm-level variables that are specific to firms producing the standardized variety are denoted by the superscript z. Throughout, we assume that the production of a standardized variety is associated with sunk fixed costs $a(z_{ijk})$.

Firms producing the non-standardized variety. Profits of firms that decide to produce a non-standardized variety are given by

$$\pi_{ijk}(\varphi) = \frac{x_{ijk}(\varphi)}{\sigma_k} - f_{ijk}, \tag{25}$$

where sales are given by

$$x_{ijk}(\varphi) = A_{jk}\left(\frac{\sigma_k}{\sigma_k - 1}\frac{\tau_{ijk}}{\varphi}\right)^{1-\sigma_k}, \tag{26}$$

where $A_{jk} = P_{jk}^{\sigma_k - 1}X_{jk}$.

Firms producing the standardized variety. Profits of firms producing a standardized good with productivity φ from country i selling to country j and choosing the price optimally are given by

$$\pi^z_{ijk}(\varphi) = \frac{x^z_{ijk}(\varphi)}{\sigma_k} - f_{ijk} - a(z_{ijk}), \tag{27}$$

where sales are given by

$$x^z_{ijk}(\varphi) = A_{jk}\left(\frac{\sigma_k}{\sigma_k - 1}\frac{\tau_{ijk}}{\varphi}\right)^{1-\sigma_k} z_{ijk}^{(\sigma_k-1)(1-t_k)}, \tag{28}$$

Productivity cut-offs for a national standard

There are two productivity cut-offs. The cut-off $\bar{\varphi}^n_{ijk}$ is given by the firm that is indifferent between producing the standardized and the non-standardized variety.

$$\frac{A_{jk}}{\sigma_k}\left(\frac{\sigma_k}{\sigma_k - 1}\frac{\tau_{ijk}}{\varphi}\right)^{1-\sigma_k} z_{jk}^{(\sigma_k-1)(1-t_k)} - f_{ijk} - a(z_{jk}) = \frac{A_{jk}}{\sigma_k}\left(\frac{\sigma_k}{\sigma_k - 1}\frac{\tau_{ijk}}{\varphi}\right)^{1-\sigma_k} - f_{ijk} \tag{29}$$

The resulting productivity cut-off to produce standardized varieties is

$$\bar{\varphi}^n_{ijk} = \left(\frac{\sigma_k a(z_{jk})}{s(z_{jk})A_{jk}}\right)^{\frac{1}{\sigma_k - 1}} \frac{\sigma_k}{\sigma_k - 1}\tau_{ijk}. \tag{30}$$

where $s(z_{jk}) = z_{jk}^{(\sigma_k-1)(1-t_k)} - 1$. In addition, there is a cut-off productivity $(\bar{\varphi}_{ijk})$ below which firms will not sell in country j because the potential revenues cannot cover production and fixed costs of exporting to j. This cut-off is obtained by setting the profits of a non-standardized variety equal to zero:

$$\bar{\varphi}_{ijk} = \left(\frac{\sigma_k f_{ijk}}{A_{jk}}\right)^{\frac{1}{\sigma_k - 1}} \frac{\sigma_k}{\sigma_k - 1}\tau_{ijk} \tag{31}$$

Productivity cut-offs for a harmonized standard

Firms have cost complementarities and need to pay the sunk investment cost for the harmonized standard $a(z_k)$ in one market only. The cut-off $\bar{\varphi}^h_{ijk}$ is given by the firm that is indifferent between producing the standardized and the non-standardized variety

$$\begin{aligned} &\frac{A_{ik} + A_{jk}\tau_{ijk}^{1-\sigma_k}}{\sigma_k}\left(\frac{\sigma_k}{\sigma_k - 1}\frac{1}{\varphi}\right)^{1-\sigma_k} z_k^{(\sigma_k-1)(1-t_k)} - f_{iik} - f_{ijk} - a(z_k) = \\ &= \frac{A_{ik} + A_{jk}\tau_{ijk}^{1-\sigma_k}}{\sigma_k}\left(\frac{\sigma_k}{\sigma_k - 1}\frac{\tau_{ijk}}{\varphi}\right)^{1-\sigma_k} - f_{iik} - f_{ijk} \end{aligned} \tag{32}$$

and the associated productivity cut-off equals:

$$\bar{\varphi}^h_{ijk} = \left(\frac{\sigma_k a(z_k)}{s(z_k)\left(A_{ik} + A_{jk}\tau_{ijk}^{1-\sigma_k}\right)}\right)^{\frac{1}{\sigma_k - 1}} \frac{\sigma_k}{\sigma_k - 1} \tag{33}$$

where $s(z_k) = z_k^{(\sigma_k-1)(1-t_k)} - 1$.

Implied assumptions in order to have partitioning

As in Melitz (2003), we assume that the values for fixed and marginal costs are such that there is partitioning into exporters and importers. In particular, this condition can be derived as follows. Let $\bar{\varphi}_{iik}$ denote the domestic production cut-off derived from the zero profit condition for domestic sales:

$$\pi_{iik}(\bar{\varphi}_{iik}) = \frac{1}{\sigma_k}A_{ik}\left(\frac{\sigma_k}{\sigma_k - 1}\frac{1}{\bar{\varphi}_{iik}}\right)\frac{1}{\sigma_k} - f_{iik} = 0 \tag{34}$$

$$\bar{\varphi}_{iik} = \frac{\sigma_k}{\sigma_k - 1}\left(\frac{f_{iik}}{A_{ik}}\right)^{\frac{1}{\sigma_k - 1}} \tag{35}$$

Partitioning into exporters and non-exporters occurs if:

$$\pi_{iik}(\bar{\varphi}_{iik}) < 0 \tag{36}$$

$$f_{iik}\frac{A_{jk}}{A_{ik}} < f_{ijk}\tau_{ijk}^{\sigma_k - 1} \tag{37}$$

The condition for partitioning into exporters that produce according to the standard z_{jk} or not can be derived similarly:

$$\pi^n_{ijk}(\bar{\varphi}_{ijk}) < 0 \tag{38}$$
$$f_{ijk}s(z_{jk}) < a(z_{jk}) \tag{39}$$

This condition implies that the ratio of sunk investment costs and fixed costs of exporting is such that only high-productivity exporters are able to adapt their product to the foreign standard.

Gravity equation for national standards

We can write total bilateral export sales of country i to country j as

$$X_{ijk} = \int_{\omega \in \Omega_{ij}} x_{ijk}(\omega) dG(\omega), \tag{40}$$

as the sum of the sales of firms that produce the standardized varieties (firms with productivity in the interval $\bar{\varphi}^n_{ijk} < \varphi < \infty$) and firms that produce the non-standardized variety (firms with productivity in the interval $\bar{\varphi}_{ijk} < \varphi < \bar{\varphi}^n_{ijk}$):

$$\begin{aligned} X_{ijk} =& A_{jk} \left(\frac{\sigma_k \tau_{ijk}}{\sigma_k - 1} \right)^{1-\sigma_k} M_{ijk} \\ & \left(\frac{\tilde{M}_{ijk}}{M_{ijk}} \left(\tilde{\varphi}_{ijk} \right)^{\sigma_k - 1} + \frac{\tilde{M}^n_{ijk}}{M_{ijk}} z_{ijk}^{(\sigma_k-1)(1-t_k)} \left(\tilde{\varphi}^n_{ijk} \right)^{\sigma_k - 1} \right), \end{aligned} \tag{41}$$

where $\tilde{M}_{ijk}$ is the number of firms producing the non-standardized varieties with average productivity $\tilde{\varphi}_{ijk}$ and $\tilde{M}^n_{ijk}$ is the number of firms producing the standardized varieties with average productivity $\tilde{\varphi}^n_{ijk}$.

Average productivity for firms producing the non-standardized varieties is defined as

$$\tilde{\varphi}_{ijk} = \left(\int_{\bar{\varphi}_{ijk}}^{\bar{\varphi}^n_{ijk}} \varphi^{\sigma_k - 1} d \frac{G(\varphi)}{G(\bar{\varphi}^n_{ijk}) - G(\bar{\varphi}_{ijk})} \right)^{\frac{1}{\sigma_k - 1}}, \tag{42}$$

which we can simplify to

$$\begin{aligned} \left(\tilde{\varphi}_{ijk} \right)^{\sigma_k - 1} =& \left[\left(\bar{\varphi}^n_{ijk} \right)^{-\xi_k} - \left(\bar{\varphi}_{ijk} \right)^{-\xi_k} \right]^{-1} \frac{\xi_k}{\xi_k - (\sigma_k - 1)} \\ & \left[\left(\bar{\varphi}^n_{ijk} \right)^{-\xi_k + (\sigma_k - 1)} - \left(\bar{\varphi}_{ijk} \right)^{-\xi_k + (\sigma_k - 1)} \right]. \end{aligned} \tag{43}$$

Using the fact that we can express the cut-offs in terms of the share of exporters producing the standardized variety $w_{ijk} = \bar{\varphi}^n_{ijk} / \bar{\varphi}_{ijk}$, we get

$$\left(\tilde{\varphi}_{ijk} \right)^{\sigma_k - 1} = \left(\bar{\varphi}_{ijk} \right)^{\sigma_k - 1} \frac{\xi_k}{\xi_k - (\sigma_k - 1)} \frac{1 - (w_{ijk})^{-\xi_k + (\sigma_k - 1)}}{1 - (w_{ijk})^{-\xi_k}} \tag{44}$$

Similarly, the average productivity for firms producing the standardized varieties is defined as:

$$\tilde{\varphi}^n_{ijk} = \left(\int_{\bar{\varphi}^n_{ijk}}^{\infty} \varphi^{\sigma_k - 1} d \frac{G(\varphi)}{1 - G(\bar{\varphi}^n_{ijk})} \right)^{\frac{1}{\sigma_k - 1}} \tag{45}$$

Plugging in the average productivities and substituting $\tilde{M}^n_{ijk}/M_{ijk} = (w_{ijk})^{-\xi_k}$, we the gravity equation with the extensive and intensive margin is written as

$$X^n_{ijk} = \underbrace{\left(\frac{A_{jk}}{\sigma_k f_{ijk}} \right)^{\frac{\xi_k}{(\sigma_k - 1)}} \left(\frac{\sigma_k}{\sigma_k - 1} \tau_{ijk} \right)^{-\xi_k} M_{ik}}_{\text{Extensive margin}} \underbrace{\Gamma_k f_{ijk} \left(1 + \Delta^n_{ijk} s(z_{jk}) \right)}_{\text{Intensive margin}} \tag{46}$$

where the weight is defined as: $\Delta^n_{ijk} = w_{ijk}^{-\xi_k + (\sigma_k - 1)} = \left(\frac{s(z_{jk}) f_{ijk}}{a(z_{jk})} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1}$ and $\Gamma_k = \frac{\xi_k \sigma_k}{\xi_k - (\sigma_k - 1)}$.

Gravity equation for harmonized standards

We can follow the same steps as above. The difference is that the ratio of exporters producing the harmonized standardized variety is now defined as:

$$\frac{\bar{\varphi}^h_{ijk}}{\bar{\varphi}_{ijk}} = \left(\frac{a(z_k)}{s(z_k) \left(A_{ik} + A_{jk} \tau_{ijk}^{1-\sigma_k} \right)} \frac{A_{jk} \tau_{ijk}^{1-\sigma_k}}{f_{ijk}} \right)^{\frac{1}{\sigma_k - 1}} \tag{47}$$

The corresponding gravity equation with the extensive and intensive margin is written as

$$X^h_{ijk} = \underbrace{\left(\frac{A_{jk}}{\sigma_k f_{ijk}} \right)^{\frac{\xi_k}{(\sigma_k - 1)}} \left(\frac{\sigma_k}{\sigma_k - 1} \tau_{ijk} \right)^{-\xi_k} M_{ik}}_{\text{Extensive margin}} \underbrace{\Gamma_k f_{ijk} \left(1 + \Delta^h_{ijk} s(z_k) \right)}_{\text{Intensive margin}} \tag{48}$$

where the term $\Delta^h_{ijk} = \left(\frac{s(z_k) \left(A_{ik} + A_{jk} \tau_{ijk}^{1-\sigma_k} \right)}{a(z_k)} \frac{f_{ijk}}{A_{jk} \tau_{ijk}^{1-\sigma_k}} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1}$ captures the share of exporters that produce according to the product standard.

Cost complementarity and demand effect

Comparing the situation of harmonized and national standards, we can separate the two described effects:

$$X^h_{ijk} - X^n_{ijk} = \left\{ \underbrace{\left(\lambda^h - \lambda^n \right) s(z_{jk})^{\frac{\xi_k}{\sigma_k - 1}}}_{\text{cost complementarity effect}} + \underbrace{\lambda^h \left(s(z_k)^{\frac{\xi_k}{\sigma_k - 1}} - s(z_{jk})^{\frac{\xi_k}{\sigma_k - 1}} \right)}_{\text{demand effect}} \right\} \tag{49}$$

where

$$\lambda^h = \left(\frac{f_{ijk}}{a(z_k)} \frac{\left(A_{ik} + A_{jk}\tau_{ijk}^{1-\sigma_k}\right)}{A_{jk}\tau_{ijk}^{1-\sigma_k}} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1} \tag{50}$$

$$\lambda^n = \left(\frac{f_{ijk}}{a(z_{jk})} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1} \tag{51}$$

summarize cost and market size parameters. λ^h is larger than λ^n due the second term in equation 50 being larger than one. We assume that fixed investment costs for z_k and z_{jk} are the same: $s(z_k) = s(z_{jk})$.

Marginal effects

Based on our difference-in-difference identification strategy, the marginal effect that captures the increase in trade due to harmonization is given by the term $\Delta_{ijk}^h s(z_k)$. This marginal effect depends on destination market size A_{jk}, home market size A_{ik} and trade costs τ_{ijk}. We first compute the marginal effect with respect to destination market size:

$$\frac{\partial \Delta_{ijk}^h s(z_k)}{\partial A_{jk}} = -\left(\frac{\xi_k}{(\sigma_k - 1)} - 1 \right) \left(\frac{s(z_k) f_{ijk}}{a(z_k)} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1} \left(1 + \frac{A_{ik}}{A_{jk}\tau_{ijk}^{1-\sigma_k}} \right)^{\frac{\xi_k}{\sigma_k - 1} - 2} \left(\frac{s(z_k) A_{ik}}{A_{jk}^2 \tau_{ijk}^{1-\sigma_k}} \right) < 0 \tag{52}$$

The partial derivative with respect to home market size is:

$$\frac{\partial \Delta_{ijk}^h s(z_k)}{\partial A_{ik}} = \left(\frac{\xi_k}{(\sigma_k - 1)} - 1 \right) \left(\frac{s(z_k) f_{ijk}}{a(z_k)} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1} \left(1 + \frac{A_{ik}}{A_{jk}\tau_{ijk}^{1-\sigma_k}} \right)^{\frac{\xi_k}{\sigma_k - 1} - 2} \frac{s(z_k)}{A_{jk}\tau_{ijk}^{1-\sigma_k}} > 0 \tag{53}$$

The partial derivative with respect to trade costs is:

$$\frac{\partial \Delta_{ijk}^h s(z_k)}{\partial \tau_{ijk}} = (\xi_k - \sigma_k + 1) \left(\frac{s(z_k) f_{ijk}}{a(z_k)} \right)^{\frac{\xi_k}{\sigma_k - 1} - 1} \left(1 + \frac{A_{ik}}{A_{jk}\tau_{ijk}^{1-\sigma_k}} \right)^{\frac{\xi_k}{\sigma_k - 1} - 2} \left(\frac{s(z_k) A_{ik}}{A_{jk}\tau_{ijk}^{2-\sigma_k}} \right) > 0 \tag{54}$$

A larger destination market size attracts relative more firms exporting the non-standardized variety, which decreases the share of firms that export the standardized variety and reduces the marginal effect of harmonized standards. For the home market size, a larger domestic markets increases the positive effect of cost complementarities and induces more firms to produce according to the standard. Higher trade costs increase the share of firms exporting the standardized variety and increase the marginal effect of harmonized standards.

B Appendix: ICS

Table 13: International classification of standards (ICS)

ICS class	Description
1	Generalities. Terminology. Standardization. Documentation.
3	Services. Company organization, management and quality. Administration. Transport. Sociology.
7	Mathematics. Natural sciences.
11	Health care technology.
13	Environment. Health protection. Safety.
17	Metrology and measurement. Physical phenomena.
19	Testing.
21	Mechanical systems and components for general use.
23	Fluid systems and components for general use.
25	Manufacturing engineering.
27	Energy and heat transfer engineering.
29	Electrical engineering.
31	Electronics.
33	Telecommunications. Audio and video engineering.
35	Information technology. Office machines.
37	Image technology.
39	Precision mechanics. Jewelry.
43	Road vehicles engineering.
45	Railway engineering.
47	Shipbuilding and marine structures.
49	Aircraft and space vehicle engineering.
53	Materials handling equipment.
55	Packaging and distribution of goods.
59	Textile and leather technology.
61	Clothing industry.
65	Agriculture.
67	Food technology.
71	Chemical technology.
73	Mining and minerals.
75	Petroleum and related technologies.
77	Metallurgy.
79	Wood technology.
81	Glass and ceramics industries.
83	Rubber and plastic industries.
85	Paper technology.
87	Paint and colour industries.
91	Construction materials and building.
93	Civil engineering.
95	Military engineering.
97	Domestic and commercial equipment. Entertainment. Sports.
99	(No title)

Source: ISO

C Appendix: Database construction

The original dataset comprises individual standards for which the date of release, the ICS class, the nationality of the standard-setting organization (SSO) as well as the duplicate versions in other SSOs are known ("links" to other standards). We denote these duplicates as "equivalences". The nationality of an SSO can either be a country ("national") or a European or international SSO ("international").

Linking all equivalent standards to one another

The original Perinorm dataset (which is part of the Searle Center Database on Technology Standards, Industry Consortia and Innovation) explicitly comprises a column where standard equivalences are listed; these essentially represent accreditations of a previously released standard by another SSO or the simultaneous release of a standard by more than one SSO. However, due to misreporting or chronological reporting, a single standard observation does not necessarily reveal all equivalences. In the case of chronological reporting, only equivalences known at the time of the release are listed and subsequent equivalences are only reported for newly released standards. For these reasons, one may for example encounter the following situation:

Table 14: Example of incomplete equivalences

Standard ID	Release date	Nationality of SSO	Equivalence
A	01/01/2000	FR	B
B	05/06/2005	DE	A, C
C	31/07/2012	FR	
D	04/08/2008	AT	B

All four standards, A, B, C and D, are equivalent, but this is not obvious when examining standards individually due to the incompleteness of the equivalence listings (which is most likely due to the fact that they were recorded in chronological order, i.e. when standard B was released, standard D did not yet exist, which is why it is not explicitly listed under its equivalences). For the purpose of identifying the originating country, we need to have the full information on these equivalences to determine which of the standards A, B, C or D was first released (standard A in the above example), and thus represents the original standard. All other standards, B, C and D, are then classified as accreditations of standard A.[35]

We use graph theory to identify all standards that belong to one group by assigning them the same group identifier.[36] In particular, we use the following breadth-first search algorithm (which we specifically adapt to the structure of the dataset) to connect all standards by exploring their equivalences:

[35]The accreditation of standard A due to the release of standard C is irrelevant information for our research question, as it concerns a within-country accreditation; we will thus drop the observation on standard C in the final dataset.

[36]We particularly thank François Farago for helping us with this procedure.

1. Initialize the group identifier, equal to a standard's row number in the dataset, for each standard.
2. Starting with $n = 1$, store the group identifier of standard n in the database (i.e. A).
3. Add the group identifiers of the equivalent standards, i.e. B, to the vector of stored group identifiers.
4. Note the smallest element of the vector of stored group identifiers.
5. Modify the group identifiers of standard n and its equivalent standards by assigning them the value identified in step 4 (i.e. A and B will have the same group identifier).
6. Delete the stored group identifiers.
7. Go on to the next standard $n + 1$ and repeat from step 2 onwards.

In order to minimize the computing power needed to run the algorithm, we use a simple hash function to build a dictionary of all standards whose IDs, which are strings, are mapped one-to-one to numeric values.

Identifying "originating country" and "accrediting country"

Once all equivalent standards have been grouped together, we identify the "originating country" by the nationality of the SSO who first released the standard. The nationalities of SSOs who released equivalent standards at a later date are used to classify the "accrediting countries". As such, a standard should have one originating country and one or several accrediting countries.

However, it is also possible that two or more SSOs release a standard at the same date.[37] International SSOs also constitute a "country" (country code "IX" in Figure 5). If two countries each released a standard at the same time, the respective standard is counted both as an original standard as well as an accreditation. However, if an international SSO and a national SSO release a standard at the same time, we consider that this standard originated in the international SSO (as it is very likely that the national SSO is a member organization of the international SSO and simply accredits standards of the international SSO at the same date as the latter one releases the standard). If two national SSOs are releasing a standard at the same time, both nationalities are registered as originating and accrediting countries.

Obtaining the relevant sub-sample

We eliminate the following standards to obtain the relevant subsample of all standard harmonizations:

[37]This situation arises most obviously when the date of the release is exactly the same. However, for some standards, only the year of the release is known, and in this case, two standards with the same release year will also be considered to have been released at the same date despite the fact that we cannot rule out the possibility that they were released at different dates over the course of the same year.

1. Standards that exist by themselves and are not linked to any other standard, meaning there is no other equivalent standard in the database.
2. Standards that constitute pure within-country accreditations or accreditations of a foreign standard after it was already accredited by another SSO of the same nationality.
3. Original national standards that were subsequently only released by SSOs of the same nationality.

Table 15: Procedure to define subset of data

Initial number of standards	1372038
Standards that are not linked to other standards (step 1)	545315
Duplicate accreditations within one country (step 2)	275309
Remaining national standards (step 3)	194160
Remaining standards in database	530645
of which: original bilateral standards	3250
of which: accreditations of bilateral standards	26790
of which: by national SSOs	24658
of which: by international SSOs	2132
of which: original international standards	73344
of which: accreditations of international standards	427261

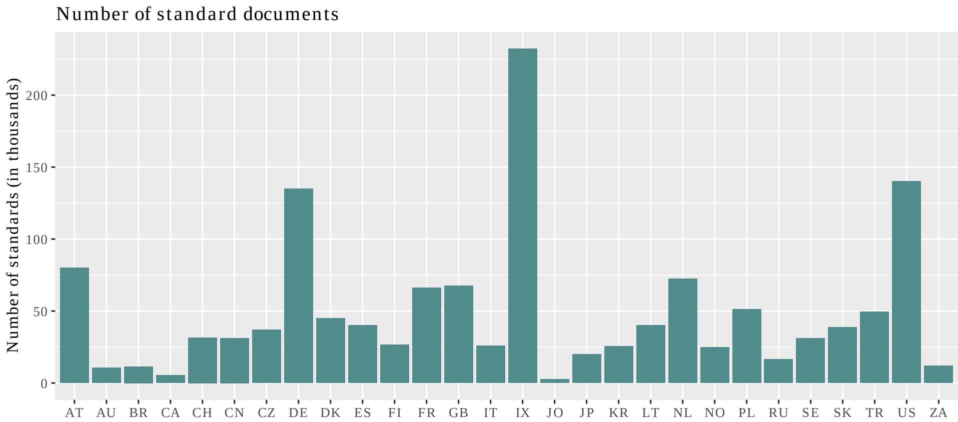
Notes: The table displays the number of standard releases over the years 1995–2014, broken down by national and harmonized standards. The latter are also broken down by their means of accreditation. Bilateral standards are those harmonized standards that are released/accredited by national SSOs only while international standards are those that originate in international SSOs.

Figure 5 (a) displays the country distribution of the raw data. We note the strong representation of Austrian, German and US standards. Besides the non-excludable possibility that these countries are very active in the standard-setting process, this could be due to more comprehensive reporting for the SSOs of these countries as well as the duplicate release of the same standard within one country due to institutional practices. Figure 5 (b) displays the country distribution of the relevant subset for our analysis: the dominance of Austrian, German and US standards vanishes in the subsample.

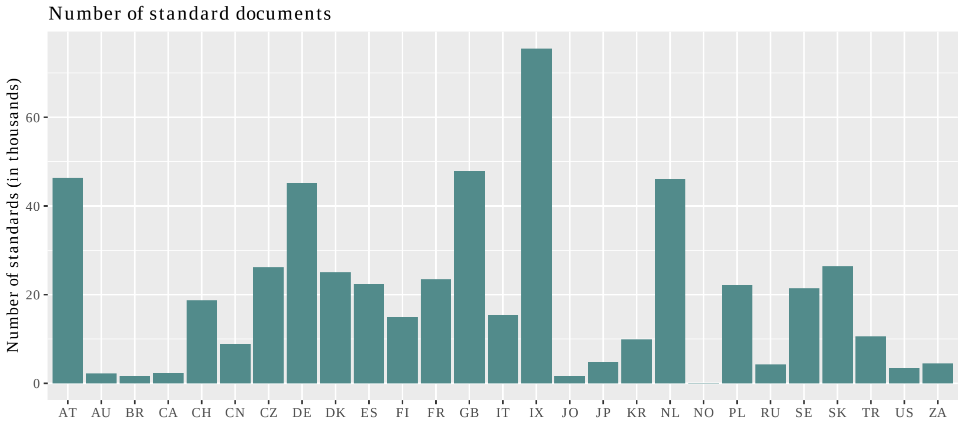
The data presented in Figure 5 show that a large number of standards documents are released by international SSOs. A large amount of this international dimension of standard harmonization is due to the European integration process and the accompanying dominance of European SSOs among international SSOs. Table 16 lists the largest international SSOs (in terms of original standards). As their names reveal, many of these SSOs are European ones. However, it should be noted that many of these SSOs were founded as part of the European integration process, but also produce international standards and are comprised of non-European members (one such example is ETSI).

Figure 5: Country distribution before and after cleaning

(a) Raw data



(b) Relevant subset



Notes: The figure displays the number of standards, broken down by the nationality of the respective SSO. The data are summed over the years 1995–2014 and all ICS classes. Panel a displays the distribution based on the original dataset, while panel b displays the distribution after the data have been cleaned according to the criteria described in this appendix.

Table 16: Top ten international SSOs (release of original standards)

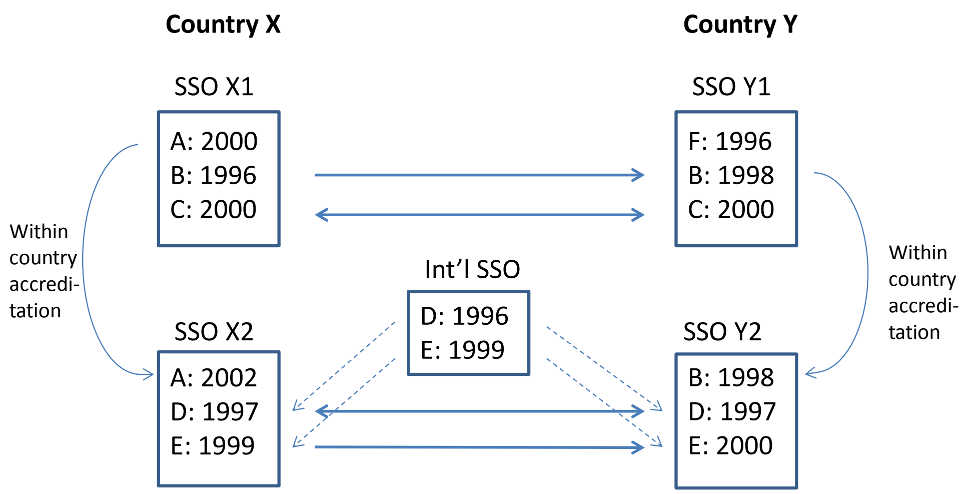
SSO	Number	in %
CEN – European Committee for Standardization	26747	36.5
ISO – International Organization for Standardization	18995	25.9
IEC – International Electrotechnical Commission	13344	18.2
CENELEC – European Comm. for Electrotechnical Standardization	6820	9.3
ETSI – European Telecommunications Standards Institute	4815	6.6
ASD – AeroSpace and Defence Industries Association of Europe	1467	2.0
ITU – International Telecommunication Union	371	0.5
ECMA – European Asso. f. Standardizing Info. and Comm. Systems	140	0.2
ECSS – European Cooperation for Space Standardization	107	0.1
CCSDS – Consultative Committee for Space Data Systems	90	0.1
Other	448	0.6
Total	73344	100

Notes: The table displays the number of original standards of international SSOs, broken down by SSO. A standard can be released by more than one SSO per year and can thus be counted several times. The data are summed over the years 1995–2014 and all ICS classes.

Construction of identifiers for harmonization events

A standard document can either be a national standard, meaning that it was released by a national SSO and never accredited by an SSO of another nationality (such as standards A and F in Figure 6), or a harmonized standard, meaning that at least two versions of the same unique standard have been released by at least two SSOs of different nationalities (such as standards B, C, D and E in Figure 6).

Figure 6: Terminology



We consider a standard harmonization event to take place whenever the importer of a product accredits a standard that was already released or is being released in the same year by the exporter. As demonstrated in Figure 6, this can be the case when country Y accredits the standard B in 1998 that was originally released by country X in 1996. A harmonization event also takes place whenever two countries accredit a standard that was originally released by an international SSO. In the example in Figure 6, this is the case for standards D and E.

Table 17: Coding of harmonization events

Exporter	Importer	Year	Harm. events	Dummy
X	Y	1996	–	0
X	Y	1997	D	1
X	Y	1998	B	1
X	Y	1999	–	0
X	Y	2000	C + E	1
Y	X	1996	–	0
Y	X	1997	D	1
Y	X	1998	–	0
Y	X	1999	–	0
Y	X	2000	C	1

In Table 17, we show how we code the harmonization events. The year of the harmonization is the point in time when the importing country accredits the standard, i.e. 1998 for the case of standard B in the example of Figure 6. When the two countries accredit the same standard in the same year, as is the case of standard C in the example, we record it as a harmonization event both when considering exports from X to Y in the year 2000 as well as exports from Y to X in the year 2000.

D Appendix: Concordance table

One of the key identification issues in quantifying the impact of standard harmonization on international trade is linking the standard documents to their corresponding products. The International Standard Classification (ICS) system groups standards according to economic sector, the underlying technology or activity, such as environmental protection, safety assurance or protection of public health. On the other hand, products in international trade data are categorized according to the Harmonized System (HS) established by the World Customs Organization (WCO).

The HS nomenclature follows trade policy concerns such as tariffs and not necessarily the production characteristics of the product. The non-existence of a concordance is one of the main reasons why previous papers in the literature cover only certain industries; see Moenius (2006), Reyes (2011) or Fontagné et al. (2015). This paper tackles the concordance issue in two ways. First, we use a newly developed concordance table from the WTO with the drawback that some links between key standard categories and products are missing. As a second step, we develop an alternative all-industry concordance table using keyword-matching techniques. We briefly describe both approaches below.

Concordance table based on WTO's TBT IMS database

The WTO concordance table is based on the Technical Barriers to Trade Information Management System (TBT IMS) database of the WTO. The TBT IMS is a publicly available database of transparency information provided by WTO members in relation to technical regulations, conformity assessment procedures and standards.[38] A typical notification of a member country consists of an explanation of why it imposes a technical barrier to trade, which partner country is affected, the ICS classification of the TBT and, in some instances, it also includes the 4-digit HS code (in some instances the 2-digit or the 6-digit code) for the products on which the measure is applied.

All the notified relationships between HS and ICS classes for the period 2000 to 2016 amount to 3775 notifications, of which several mention one or more HS and ICS classes. There are a total of 2391 links between HS and ICS, and these make up 0.5% of all possible links. Of the identified relationships, 32% cover multiple relationships and lead to a many-to-many concordance. One of the drawbacks of this concordance table is potential underreporting because there will only be links for those HS-ICS relationships for which there was actually a notification at the WTO. In addition, there might be biased reporting, as WTO members have different incentives to report to the WTO depending on the importance of the export and import flows pertaining to a particular product.

Concordance table based on keyword matching

We use a rich set of fixed effects to tackle the issues mentioned above. However, identification concerns of neglecting key standard-product links remain. To mitigate this concern, we

[38]The table is available at https://i-tip.wto.org/goods/Forms/Methodology.aspx.

construct another concordance table based on keyword-matching techniques described in a companion paper (Han et al., 2019). The main idea is to use keywords describing individual standards (obtained from the German Institute for Standardization DIN, Deutsches Institut für Normung e.V.) and match them with keywords extracted from the descriptions of the product categories in the Harmonized System.

The first step reduces the set of keywords via a stemming algorithm. We consider only the present tense of a verb and the singular of a noun. After having unified each word, a keyword algorithm extracts all the keywords from the HS and ICS classification and attaches an importance weight to each of them. The importance weight is determined by the inverse-document frequency (how distinctive the word is in the overall classification scheme). We then calculate the combined weight for each HS 4-digit and ICS 5-digit category and normalize this combined weight by the number of keywords in each classification scheme. We then choose a threshold below which we consider the respective HS-ICS links as irrelevant. This threshold value is chosen to keep as many of the links that appear in the WTO concordance table as possible while reducing the total number of links.

We obtain a concordance table with 994 links between the ICS 5-digit and HS 4-digit categories. Given that the quality of the match is not as good as the one by the WTO (which is based on human knowledge), we use this table as a robustness check. The advantage of the keyword-matching algorithm is that it is unbiased and comprehensive.

E Appendix: Additional empirical results

Multiple harmonization events

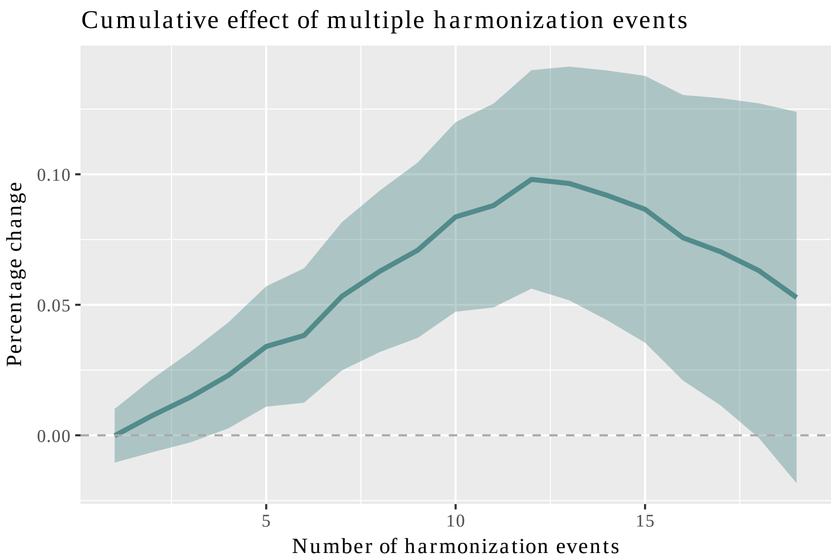
In contrast to most difference-in-difference set-ups, each exporter-importer-product triplet can be subject to multiple treatments over the time period in question. The baseline specification estimates the marginal effect of a standard harmonization event on trade flows relative to non-harmonized flows, assuming that this effect is constant. However, the positive effects of standard harmonization might take time to materialize. For this reason, we consider a non-parametric specification, where we allow the marginal effect to depend on the number of times a product experienced a harmonization event. The corresponding regression specification looks as follows, where the subscript n indexes the n-th harmonization:

$$\log(X_{ijkt}) = \sum_{n}^{20} \beta_n h_{n,ijkt} + f_{ikt} + f_{jkt} + f_{ijt} + f_{ijk} + \varepsilon_{ijkt} \tag{55}$$

The dummy $h_{n,ijkt}$ equals 1 if a product was harmonized n times and zero otherwise. The variable measures the difference in the average trade flow of a product that was harmonized n times compared to a product that was never harmonized.

Figure 7 plots the coefficients β_n from the above-specified regression set-up together with the 95% confidence interval. Panel a shows that the marginal effect of standard harmonization on trade flows is more or less constant in the number of harmonization events (up to 12-13 events), with each subsequent harmonization contributing a similar positive amount to overall trade flows. Afterwards the additional effect declines slightly, but the overall effect remains positive.

Figure 7: Cumulative effect of multiple harmonization events



Notes: The figure displays the coefficient estimates of a regression of the respective dependent variable (designated in figure subtitles) on dummies for each subsequent harmonization within an exporter-importer-product triplet (regression specification 55). Shaded regions represent 95% confidence intervals.

Results using the keyword-matching table

All results in the main part of the paper are obtained using the concordance table extracted from the WTO's TBT IMS database. As a further robustness check, we run the regression on the dataset using the concordance table obtained via keyword-matching techniques. Results for the baseline regression specification 17 are displayed in Table 18 and show similar, though slightly smaller coefficients.

Table 18: Regression results / Concordance based on keyword matching

	(1) Total	(2) Total	(3) Total
Harm.	0.09946*** [0.000]	0.01841*** [0.000]	0.00406*** [0.000]
Exporter-time FE	yes	no	no
Importer-time FE	yes	no	no
Exporter-importer FE	yes	no	no
Exporter-product-time FE	no	yes	yes
Importer-product-time FE	no	yes	yes
Exporter-importer-time FE	no	yes	yes
Exporter-importer-product FE	no	no	yes
Observations	4306574	4260304	4260286
R^2	0.21	0.88	0.88
Adjusted R^2	0.21	0.85	0.85

Notes: Regression of the respective dependent variable (designated in column headers) on harmonization indicator. Fixed effects are included as described in the regression specification 17. Standard errors are clustered at the exporter-product-level. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.

PPML and WLS regressions

As a further robustness check, we make use of recent advances in the estimation of PPML as advocated by Silva and Tenreyro (2006) and made feasible by the use of high-dimensional fixed effects thanks to Larch et al. (2017). In particular, we regress total trade flows in levels (not in logs, thus including zero trade flows) on our variable of interest as in the baseline specification. Results are displayed in Table 19.

Estimating the model with the PPML estimator produces a slightly lower estimate for the coefficient of standard harmonization (see column (1) to (3) of Table 19). Part of this decrease is due to the higher weights that this estimator attributes to more important trade flows (see the comparison with Weighted Least Squares (WLS) results using the trade value as weight in panel (b) of Table 19).

Table 19: Regression results: PPML and Weighted Least Squares

(a) PPML

	(1) Total	(2) Total	(3) Total
Harmonization	0.12745***	0.03683***	0.00267*
	[0.000]	[0.000]	[0.061]
Exporter-time FE	yes	no	no
Importer-time FE	yes	no	no
Exporter-importer FE	yes	no	no
Exporter-product-time FE	no	yes	yes
Importer-product-time FE	no	yes	yes
Exporter-importer-time FE	no	yes	yes
Exporter-importer-product FE	no	no	yes
Observations	10694300	9815057	8622827

(b) Weighted Least Squares

	(1) Total	(2) Total	(3) Total
Harmonization	0.07325***	0.03168***	0.00339**
	[0.000]	[0.000]	[0.016]
Exporter-time FE	yes	no	no
Importer-time FE	yes	no	no
Exporter-importer FE	yes	no	no
Exporter-product-time FE	no	yes	yes
Importer-product-time FE	no	yes	yes
Exporter-importer-time FE	no	yes	yes
Exporter-importer-product FE	no	no	yes
Observations	5920146	5887935	5848855
R^2	0.44	0.96	0.99
Adjusted R^2	0.44	0.95	0.99

Notes: Regression of total trade flows on harmonization indicator. The type of estimation is specified in panel header. Fixed effects are included as described in the regression table. Robust standard errors are included. P-values are reported in brackets. ***, ** and * indicate respectively 1%, 5% and 10% significance levels.