Presenting the *StanDat* Database on International Standards
Improving Data Accessibility on Marginal Topics *

Solveig Bjørkholt†

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This article presents an original database on international standards, constructed using modern data gathering methods. StanDat facilitates studies into the role of standards in the global political economy by (1) being a source for descriptive statistics, (2) enabling researchers to assess scope conditions of previous findings, and (3) providing data for new analyses, for example the exploration of the relationship between standardization and trade, as demonstrated in this article. The creation of StanDat aims to stimulate further research into the domain of standards. Moreover, by exemplifying data collection and dissemination techniques applicable to investigating less-explored subjects in the social sciences, it serves as a model for gathering, systematizing and sharing data in areas where information is plentiful yet not readily accessible for research.

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†Doctoral Research Fellow, University of Oslo

1 Introduction

It is no coincidence that, all across the globe, credit cards are 85.6 mm long and 53.98 mm wide, webpages start with HTTP, and all certified scuba diving guides have at least 60 logged dives in open water. These seemingly unrelated occurrences find their roots in international standards – a set of guiding principles that foster global interaction, harmonization of expectations, and a world-wide sense of familiarity and predictability.

Standards are an essential aspect of the globalization process, both emerging from and enabling it. For instance, shipping containers revolutionized global trade by enabling efficient shipping, but, importantly, their adoption rate across ports depended on harmonization through standards (Levinson 2016). Indeed, the proliferation of standards has led scholars across a broad range of disciplines to study these regulatory initiatives, including their design, diversity, effectiveness and legitimacy as transnational regulatory tools (De Vries et al. 2018; Marx et al. 2012). This article aims to boost the growing body of research on international standards by introducing *StanDat*, a comprehensive database derived from the International Organization for Standardization (ISO). This database enhances access to descriptive statistics for qualitative purposes and facilitates the study of quantitative relationships, such as those between standardization and trade, innovation and economic growth (Blind et al. 2023; Swann 2010). It can also be used to address questions related to the legitimacy of standards as regulatory instruments (Bernstein and Cashore 2007) and how standardization can serve as a source of power (Rühlig 2023)[1].

Previously, access to structured data on the topic of standards has been relatively scarce, despite plenty of information being readily available on the internet. Availability of digital data does not prescribe accessibility, and the harvest- and processing requirements needed to use these data to answer research questions pose barriers to many social scientists (Lazer et al. 2009). In a time where data collection techniques has allowed for a burgeoning body of datasets within international relations[2], it is worth considering how distinct topics such as standards may become understudied

[1] See Table 2 for elaboration.

[2] For instance Zürn et al. (2021) (Authority of International Organizations), Schmidtke et al. (2023) (Legitimacy of

compared to topics with readily available datasets, potentially leading to an availability bias in the social sciences (Mahrt and Scharkow 2013). Thus, in addition to introducing the *StanDat database*, this paper shows how a full-fledged database on the domain-specific topic of standards can be constructed through web scraping and made readily available to researchers, hopefully contributing to the expansion of research in this important field (De Vries et al. 2018).

2 The politics of standards

Research on standards and standardization is incredibly diverse. First, studies span several disciplines, including management studies (Narayanan and Chen 2012; Wiegmann et al. 2017), organisational studies (Botzem and Dobusch 2012; Brunsson 2002), law (Pauwelyn et al. 2012), economics (Swann 2010; Weitzel et al. 2006; Yang 2023), sociology (Timmermans and Epstein 2010), political science (Abbott and Snidal 2001; Büthe and Mattli 2011a; Graz 2019; Mattli and Büthe 2003), and more recently, multidisciplinary approaches (Eliantonio and Cauffman 2020; Olsen 2020). Second, standards are produced and adopted at various levels, from the local to the international. Third, a wide range of topics are standardized, including for example education (Elken 2017), human capital (Yarrow 2022), child welfare (Sletten and Ellingsen 2020) and the environment (Prakash and Potoski 2006).

While it is beyond the scope of this paper to give a full overview of the standardization literature, the complexity illustrated above may explain why, despite an increasing volume of research, some scholars deem standardization to be an "under-investigated area of research" (De Vries et al. 2018, p. 57). Although the field has grown in popularity over the last decades (Yang 2023), in a bibliometric study, Heikkilä et al. (2021) found that within economic textbooks, the words "standards" and "standardization" are seldom found in the word indices, and the relationship between standardization and economic growth has never been analyzed in the top five economic journals between 1996 and 2018. Arguably, the rich albeit fragmented literature has concealed the importance

International Organizations) and Sommerer and Tallberg (2016) (Transnational Access to International Organizations).

of this broad phenomenon to many researchers (Narayanan and Chen 2012).

Yet, the political significance of standards has become increasingly evident to social scientists (Mattli 2001). A standard can be defined as a "rule for common and voluntary use" (Brunsson et al. 2012, p. 616) "that structur[es] interaction" (Botzem and Dobusch 2012, p. 739) and represents the "values against which people, practices and things are measured" (Loconto and Busch 2010, p. 526). However, despite originating from expert deliberations, these values can be quite disputed. For instance, the effort to develop standards for humane animal traps was significantly delayed due to activism from animal protection groups, who advocated for a general ban of all animal trapping devices (Hallström 2004). Another example of conflicting values and trade-offs concerns the creation of a global standard for wireless equipment. A few years after the Institute of Electrical and Electronics Engineers (IEEE) proposed the well-known Wi-Fi, China proposed the WLAN Authentication and Privacy Infrastructure (WAPI). Although WAPI promised better performance, it offered poorer privacy protections, and standard-setters settled on the Wi-Fi (Rühlig 2023).

The widespread adoption of the Wi-Fi standard also exemplifies the enduring nature of certain standards; they can produce path-dependencies. The QWERTY keyboard is a classic example within economics of how markets may lock in inferior outcomes. David (1985) argued that the QWERTY layout was designed to slow down typing on typewriters to prevent jamming, and suggested that a different layout would have been more efficient for computers. This demonstrates how standards (both de facto and de jure) can become so deeply entrenched that even suboptimal outcomes are difficult to change, benefiting some actors over others. Indeed, standards are powerful instruments for technology diffusion, and winning a "standardization battle" can have long lasting consequences. Ding (2024) has argued that diffusion, in addition to research prowess, is a core component of nations' scientific and technological power.

Within international relations, the topic of standards entered the research agenda in the 1990s, with the increased study of private actors in global governance (Peña 2015). Standards are often viewed as governance tools (Abbott and Snidal 2001), and today many scholars view standard setting bodies as a part of a "power triangle" that govern socio-economic affairs (Higgins and Hall-

ström 2007), posing a form of "transnational private authority" (Graz 2019). StanDat facilitates further studies into the significance of standards in the global economy, to explore the reasons and circumstances under which they have an impact.

3 Data source: The International Organization for Standardization (ISO)

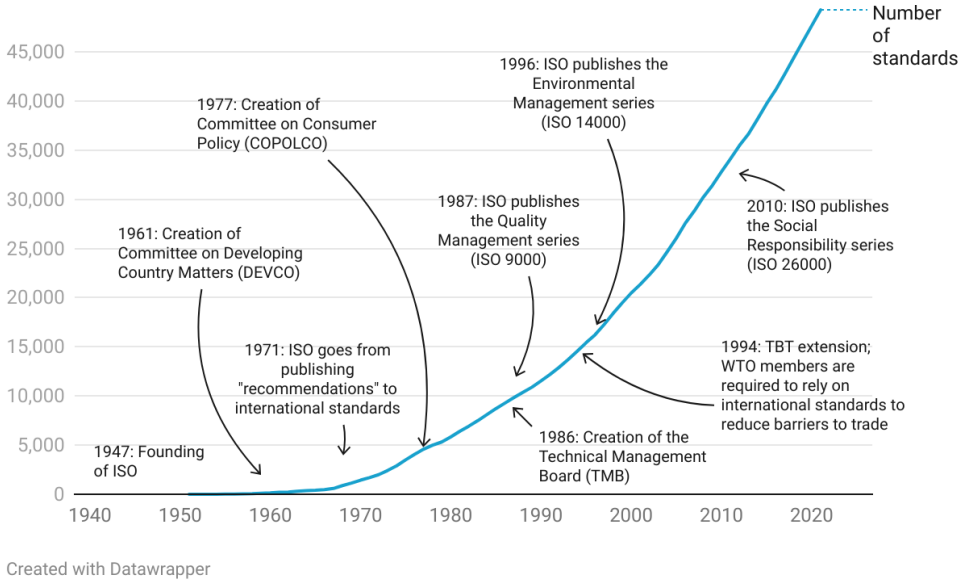


Figure 1: Growth of ISO standards over time annotated with selected notable events in ISO's history.

StanDat is built from digital data harvested from the International Organization for Standardization (ISO), one of the oldest and most active standardization organizations on the international arena (Heires 2008). Other notable international standard-setting organizations include the European Committee for Standardization (CEN), the International Accounting Standards Board (IASB), the International Telecommunication Union (ITU) and the International Electrotechnical Commission (IEC) (Büthe and Mattli 2010)[3]. While StanDat focuses on ISO standards, the approach demonstrated in this article can be used to also gather data on other organizations.

The ISO standards mapped in StanDat are global, generalist (i.e. regulate a range of topics) and

[3]In addition, many standards exist solely at the national level, and some are created de-facto in the market (Suarez 2004; Wiegmann et al. 2017). For an overview of different modes of standardization, see for example Kerwer (2005). ISO represents a *non-market based organization* producing *private* standards (Büthe and Mattli 2011b).

widely distributed. Ten years ago, they were estimated to encompass approximately 85 percent of all international product standards in collaboration with IEC (Büthe and Mattli 2011a, p. 29). At the time of writing, ISO sports a portfolio of over 25,000 standards organized within 834 technical committees and subcommittees [4].

Figure 1 gives an overview of some historical highlights along with ISO's cumulative growth of standards. In 1971, ISO transitioned from making recommendations to provide what they termed "international standards" (Murphy and Yates 2009). The 1979 Tokyo Round resulted in the Technical Barriers to Trade (TBT) Agreement, calling for nondiscriminatory, minimally trade-restrictive standards aligned with international norms (Kim 2018, p. 774). The TBT Agreement became part of GATT-WTO obligations in 1994, requiring members to harmonize technical specifications to reduce trade barriers (Jackson 1997, p. 223).

Additionally, ISO has broadened its scope, expanding from purely technical fields into new societal fields. A standard series on Quality Management and Quality Assurance (ISO 9001) was published in 1987, and since then, ISO has expanded its portfolio into Environmental Management (ISO 14001) and Social Responsibility (ISO 26000) (Hallström 2008; Hallström and Higgins 2010). Hence, ISO has expanded its reach over time, impacting a wider array of stakeholders and expanding the issue scope covered by standards. To address representation, stakeholder concerns and other challenges, ISO has established DEVCO, COPOLCO and TMB (Bijlmakers 2023).

ISO has a decentralized structure based on a network of technical committees (TCs). Member countries are represented in these TCs by their most representative national standardization body. Per date, ISO hosts 171 national member bodies, with varying degrees of engagement, activity and influence depending on membership status, degree of participation, and number of experts[5]. Besides being members in TCs, national member bodies may assume leadership roles such as secretariat, chair, or convener. The secretariat, responsible for leading TCs, is managed by a member

[4]This is a very short introduction to ISO. For further details, see for example Heires (2008), Bijlmakers (2023) and Murphy and Yates (2009).

[5]There are three member categories: full member, correspondent member, and subscriber member. Only full members can become P-members (participating members) in TCs and actively engage in committee work. Observing members are allowed to follow the process but cannot participate.

body volunteering for a specific period. It is also important to acknowledge that mere membership in a TC does not necessarily imply active participation. Meaningful engagement in negotiation processes depends on factors beyond formal membership, such as time and expertise (Alshadafan 2020).

4 The StanDat database

Table 1: Overview of the StanDat database.

Category	Datasets	Time series	Description	Source and method
Standards	Status, SDGs, Lifecycle	1951 - 2023	Data on specific standards, e.g host TC, life cycle, current status, edition, pages, sustainability goals and ICS code.	www.iso.org with sublinks to every standard. Collected using webscraping.
TC-membership	Countries, Organizations	2002/4 - 2023	Data on membership in technical committees and subcommittees, for national member bodies and organizations.	Wayback Machine. Collected using the Wayback Machine API to scrape data.
Historical	Membership, Technical committees	1947 - 2015	Membership in ISO over time, including type of membership and function of membership, and year of establishment for various TCs.	www.iso.org. Parsed from pdf in public archive (see Appendix). TC establishment scraped from webpage.
Certifications	Per country, Per industry, Per country and industry	1993 - 2020 (but varies depending on ISO series)	Certification of ISO standards. The annual ISO survey documents the number of certifications reported by certification bodies accredited by the International Accreditation Forum per country, industry and ISO series.	The ISO Survey. Parsed from excel files.

StanDat is a database comprised of four parts; "Standards", "TC-membership", "Historical" and "Certifications", where each part contains 2-3 datasets individual datasets. Units and time series coverage varies across the datasets, as shown in Table 1[6].

Due to ISO not possessing an API, the datasets are mainly derived from webscraping and parsing of ISO's webpages, with some information extracted from Excel and PDF files from their official archive. Detailed data gathering methods are described in Appendix B. StanDat complements existing datasets like Nautos (formerly Perinorm), which focuses on national and regional standards, by providing detailed information on ISO standards' standardization process, historical development, and diffusion.

Web scraping is the practice of detecting and extracting information from the HTML-pages, and parsing involves structuring information into a dataset. Despite its growing adoption across

[6]The codebook is available in Appendix A.

various social science disciplines (Luscombe et al. 2022), to the best of my knowledge, this method has not yet been employed to construct a large-scale database of the type described here. Examples of previous use include using web scraping to collect data for specific research questions (Boeing and Waddell 2017; Cavallo 2018) and introducing frameworks on how to use web scraping to collect data on specific topics (Anglin 2019; Braun et al. 2018). These are useful contributions, but come with some limitations in terms of data accessibility. The first examples do not always provide replication data, and the latter necessitates technical proficiency (Manovich 2012). In contrast, the approach presented here focuses on improving data accessibility to the wider research community, showing not only how a large scale database can be built through web scraping and parsing, but also simplifies data access without requiring technical expertise from individual users.

In essence, StanDat is created through three different procedures. The first procedure collected data for the "Standards" datasets (first row in Table 1), and involved scraping information on all standards that ISO lists on their webpages. This entails "classic scraping" of contemporary (not historical) webpages, and consisted of three steps; downloading the webpages to a local folder, extracting the relevant information from the webpages, and parsing this information into dataframes. Because ISO lists all standards ever produced on their webpages, the first standard in the "Standards" datasets is dated to 1951.

The second procedure addresses a common shortcoming with webscraping – that webpages are momentary snapshots susceptible to changes. This is the case with the "TC-membership" data; ISO only lists current TC members on their webpage, not past constellations. To address this temporal challenge, the Wayback Machine, managed by the nonprofit Internet Archive, provides a solution (Arora et al. 2016). Utilizing archived webpages enables researchers to retrieve and organize historical information, facilitating the collection of time-series data that might be absent from contemporary webpages[7].

Information gathered from the Wayback Machine is limited in two senses. First, the timeseries

[7]Blind and von Laer (2022) demonstrated the feasibility of using the Wayback Machine to gather information on TC membership, applying it to a smaller sample for their analysis.

is limited to the organization's acquisition (and continued ownership) of the domain name. Since ISO bought their domain in 2002, this marks the beginning of the "TC-membership" datasets. Second, due to the Wayback Machine's selective archival, all relevant webpages are not available for every year. Around 28 percent of the units required imputation. The imputation process was rule-based; detailed in Appendix B and validated in Appendix C. While data is available from 2002, it is recommended to use data from 2004, when there were enough snapshots to scrape sufficiently and make valid imputations.

Data validity is evaluated by assessing the correspondence between StanDat and information collected from other sources, including public documents and the United States' standardization organization ANSI. There are two types of possible error; imputing a country wrongly, leading to a false positive, and failing to observe a country membership, leading to a false negative. To quantify the validity, I employ accuracy as a metric. This metric refers to the correctness of values, here being how close the imputed values are to the reported values in the public documents. Accuracy calculates the ratio of correct observations to total observations, inclusive of false positives and negatives. The average accuracy on the time series excluding year 2002 is 88,82 [8], indicating that nearly 90 percent of the country-TC-years were correctly recorded. While this highlights an inherent uncertainty within the TC-membership dataset, the amount of bias due to wrong imputations is likely to be low since there is no systematicity in which countries' webpages the Wayback Machine records or skips. Moreover, an accuracy of almost 90 percent is quite good compared to other similar imputation efforts (Hu and Tsai 2022).

The third procedure involved parsing of other file formats, namely PDF and Excel. The "Historical" datasets are parsed from a PDF file in ISO's archive, last updated in 2015. For the "Certifications" datasets, I organized information from the ISO Survey, involving thorough cleaning, structuring, and merging of Excel sheets. The ISO Survey counts the annual number of valid certificates issued by certification bodies that have been accredited by members of the International

[8]The average accuracy including year 2002 is 76,83.

Accreditation Forum (IAF)[9]. It is important to note ISO's disclaimer when using the "Certifications" datasets: *The ISO Survey is not a database. The providers of the data are the certification bodies accredited by IAF members and they participate on a voluntary basis. The level of participation fluctuates from one edition of the survey to another and can impact the survey results especially at the country level. Interpretations of the results and any conclusions on the trends should be made with these considerations in mind.*

Concerning ethical aspects, given its novelty, web scraping lacks a direct legal framework, although an emerging body of literature addresses its ethical considerations, such as bias, privacy, and confidentiality (Krotov and Johnson 2023; Krotov et al. 2020). Adhering to these ethical guidelines and respecting web crawling limitations outlined in ISO's *robots.txt* document, I ensure compliance. Data is sourced exclusively from publicly accessible sources, not ISO's internal archives. Furthermore, practices include spacing out web requests and storing webpages locally, mitigating server load and enhancing reproducibility.

5 Applications of StanDat

The StanDat database can aid the research into standards and standardization in three important ways. First, it makes data directly available, simplifying the making of descriptive statistics. Second, it can be used to assess the scope conditions of findings from previous studies, providing insights into when and why phenomena occur. Third, because StanDat can be merged with other datasets, it can be used to explore new patterns and relationships with regard to international standards and other phenomena such as patents, global value chains, or, as demonstrated in section 6, trade.[10]

[9]For more information, see www.iso.org/the-iso-survey.

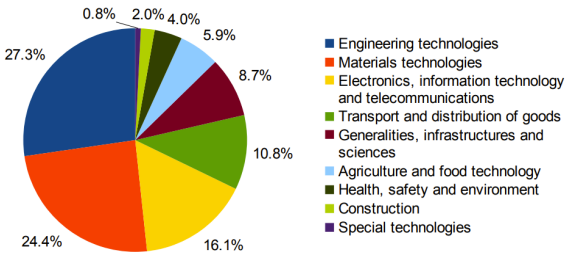
[10]While the below sections elaborate on these points, the StanDat database also has some constraints: the certification data is limited to selected standard series, there is no data on actors' perceptions of standards, and although TC membership data is available, the degree of participation is not specified.

5.1 Producing descriptive statistics

Descriptive statistics are a crucial element in both qualitative and quantitative research. StanDat offers a valuable repository of primary descriptive data, replacing previous reliance on secondary sources.

For example, Ruwet (2011), in a study on ISO's shift from producing physical standards to producing standards that also regulate societal issues, includes a graph on the distribution of ISO standards by technical sector, shown in figure 2. Such descriptive data enriches the study, but there are also some limitations due to data scarcity; the graph is gathered from ISO's 2007 annual report, thus being a few years older than the publication, confined to percentages, and does not show development over time. Since StanDat provides more recent and versatile data, it can be used to produce for example figure 3, showing cumulative growth of ISO standards across technical sectors from the organization's beginning. StanDat can also be used to tailor descriptive data more closely to the analysis at hand, for example such as figure 4, which shows the increased establishment of technical committees within the new societal sectors that Ruwet (2011) highlights.

Figure 2. Portfolio of ISO standards and draft International Standards by technical sectors in the end of 2007



Source: ISO 2007 Annual Report, p.11
http://www.iso.org/iso/fr/annual_reports.htm

Figure 2: Original illustration of proliferation and diversity of standards from Ruwet (2011).

In a different illustration, Rühlig (2023) explores diverse perspectives on the notion of technical standardization power, demonstrating China's progressive enhancement in this domain in recent years. One metric employed is the involvement in TCs, illustrated with membership data gathered from AFNOR. StanDat can be used to delve deeper into this metric, offering insights into specific

[11] Sectors in figure 2 and figure 3 correspond approximately due to ISO changing sector categories in 2017.

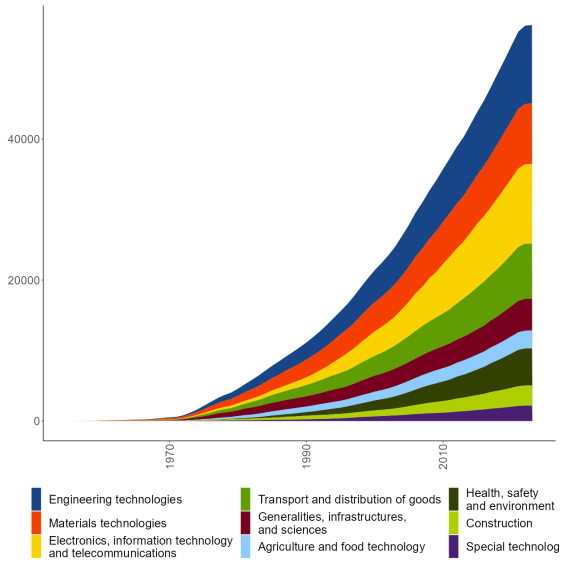


Figure 3: Illustrating the proliferation and diversity of standards (Ruwet 2011). Cumulative count of standards over time disaggregated by sector, 1950 - 2023.[11]

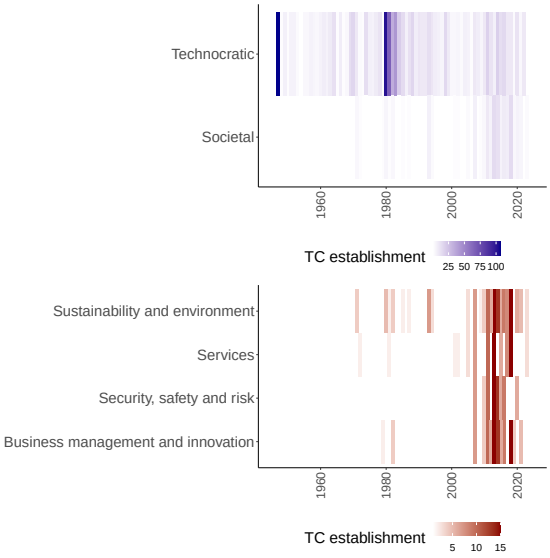


Figure 4: Illustrating ISO's shift towards making standards on societal issues (Ruwet 2011). Establishment of technical committees within technical and societal issue areas, 1950 - 2023.

sectors where China's influence has seen notable growth. While prior studies often emphasize China's ascendancy in information technology (Kim et al. 2020), figure 5 illustrates that China's P-membership in TCs has surged or remained high relative to other active countries across all sectors. This poses an interesting pattern, and highlights the potential of StanDat as a valuable resource for assessments of standardization power.

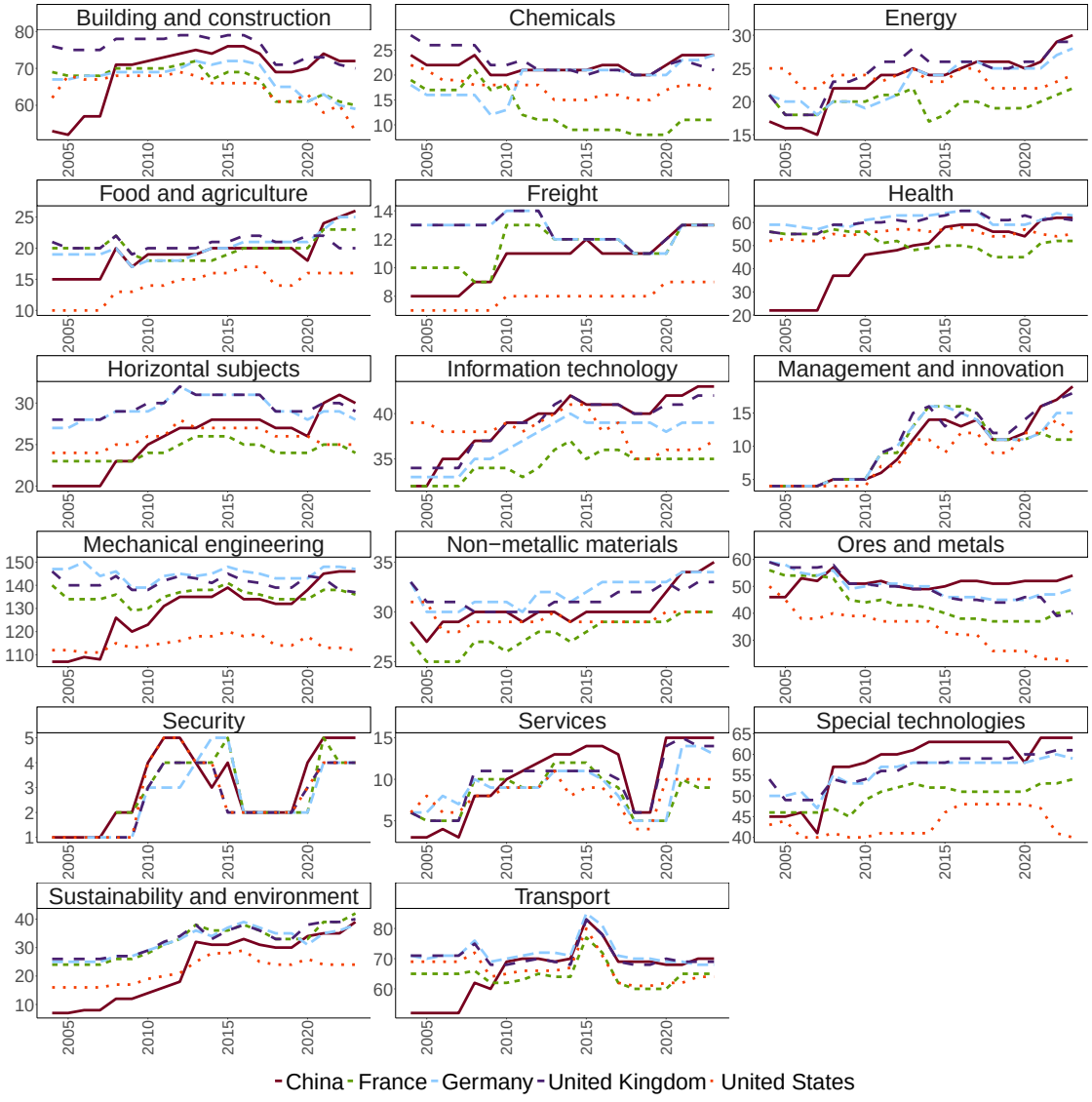


Figure 5: P-membership in technical committees (TCs) and subcommittees (SCs) in the period 2004-2023 for the most active countries as noted by (Rühlig 2023).

5.2 Assess scope conditions

The encompassing data in the StanDat database enables researchers to evaluate the scope conditions of prior studies on standardization. For instance, much research has been devoted to the causes and outcomes of ISO certification. Scholars have studied questions such as why ISO certifications spread (Sampaio et al. 2011), whether certification improves business performance (Chow-Chua et al. 2003; Link and Naveh 2006) or product innovation (Manders et al. 2016), or why firms want to pursue certification in the first place (Anderson et al. 1999). Many of these studies use surveys, often relying on the ISO Survey (Sampaio et al. 2009). Since data from the ISO Survey is only semi-structured and cumbersome to use, StanDat improves data accessibility by providing a portal to parsed and clean timeseries data. With this, scholars can quickly access ISO Survey data to extend previous analyses, and also compare ISO certification within a specific standard with other standards, as illustrated in figure 6.

This availability simplifies analysis considerably, enabling researchers to investigate whether trends observed in the certification of earlier ISO series are consistent with those of recent ISO series. For example, using a sample of 63 countries, Corbett and Kirsch (2001) and Vastag (2004) found that certification in Quality Management was an important predictor for certification in Environmental Management. Using StanDat, these studies can be extended to broader time frames, new ISO series, and more countries. This is demonstrated in an analysis in Appendix E, which, while significantly broadening the scope, largely supports the original findings. Moreover, previous ISO certifications can predict current ISO certifications, even across different topics. Quality Management certification can predict Environmental Management certification, which, in turn, can predict certification within Information Security Management. Overall, this provides valuable insights into how and why standards proliferate, even across changing technological and geopolitical circumstances.

In addition to extending older analyses, StanDat can be used to test the scope conditions of qualitative findings. For instance, Werle and Iversen (2006) argue that in standardization processes,

[12] Certifications in Africa are limited but not nonexistent.

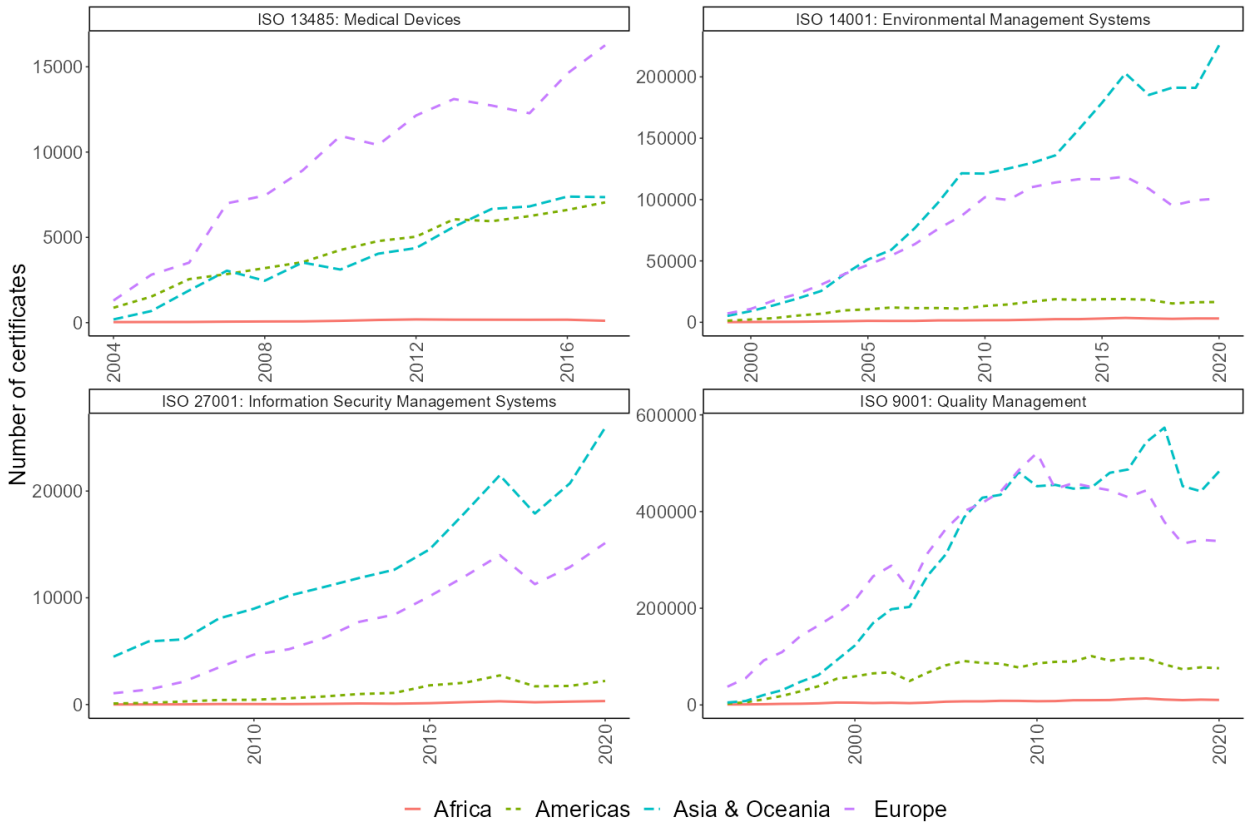


Figure 6: Number of valid certificates issued by IAF accredited certification bodies per year for selected ISO standard series, various time series.[12]

output legitimacy is more important than input legitimacy. Rühlig (2023) examines Chinese technical standardization power, providing a framework to understand standardization power which, when combined with the more general works of Blind and von Laer (2022) and Ding (2024), can be used to assess technical and scientific power among a broader set of countries. StanDat can thus be a resource for researchers aiming to evaluate the validity and reach of such theories.

5.3 Provide new analyses

Lastly, the StanDat database can contribute to new analyses within the topic of standards and standardization. In particular, because the StanDat database can be merged with other datasets, scholars can expand on studies investigating the relationship between standardization and related concepts such as economic growth, legitimacy, global value chains, membership in international organizations, foreign direct investment and innovation. A few suggestions to topics, possible

research questions, general literature and compatible datasets are given in table 2. In Appendix E, I provide an example of such an analysis, demonstrating that membership in ICT related TCs is significantly correlated with patents output in the same technologies, although with no significant difference between P-members and O-members. Section 6 is further dedicated to a new analysis.

There are numerous potential datasets for merging, with a primary identifier being country-year. Additionally, utilizing concordance tables (for example as provided by Blind (2004, p. 349)), researchers can match standards' ICS codes with other entities based on shared keys such as patents IPC codes, industry ISIC codes or trade SITC codes.

Research Topic	Examples of Research Questions	Background Literature	Complementary Datasets
Economic growth and standards	Does TC membership stimulate economic growth? Does ISO membership contribute to economic growth? How does certification relate to economic growth in emerging economies? To what extent is intra-industry trade prevalent among joint TC members? Are PTAs more common among joint TC members?	Blind and Jungmittag (2008); Ding (2024); Swann (2010)	*World Bank Development Indicators (WDI)*; Graham and Tucker (2019); *UN Comtrade*; *WTO Dispute Settlement Data*
Legitimacy of standards and standardization	What role do stakeholders play in legitimating standards? How do multi-stakeholder standardization processes influence standardization speed? Are abstracts for societal standard more similar to treaties texts than physical standards?	Bernstein and Cashore (2007); Mena and Palazzo (2012); Ruwet (2011)	*United Nations Treaty Collection*; *Factiva*; *NexisUni*; *Global Newsstream*
Global value chains (GVCs) and standards	Are countries linked by GVCs more likely to join the same TCs? Does participation in TCs boost a country's integration into GVCs?	Baglioni et al. (2020); Nadvi (2008)	Mancini et al. (2024); *Trade in Value-Added (TiVA)*; *Global Value Chain (GVC) Indicators*
ISO membership	What are the regional differences in the production of international standards? How have historical events, such as financial crises, impacted ISO membership? What has led developing countries to seek ISO membership?	Jansen (2010); Louis and Ruwet (2017)	*Correlates of War Intergovernmental Organizations (IGO)*; Graham and Tucker (2019)
Tariffs and standardization	Does joint TC membership increase dyad-wise tariff liberalization? What impact does ISO certification have on tariff liberalization?	Baccini et al. (2018)	Baccini et al. (2018) Harvard Dataverse, V1
Foreign direct investment (FDI) and standardization	Is ISO certification associated with more FDI? Does joint TC membership lead to increased FDI? Does ISO membership or membership in multiple TCs correlate with increased FDI?	Chen et al. (2014); Clougherty and Grajek (2008)	*OECD Global FDI flows*; *World Bank Development Indicators (WDI)*
Innovation and standardization	Is there a positive relationship between industry-wise TC membership and patents? What is the relationship between R&D, patenting and standardization participation? In which regions do national patents tend to precede international patents?	Blind et al. (2023); Frietsch and Schmoch (2010)	*Perinorm*; *World Intellectual Property Organization (WIPO)*; *OECD Research and Development Statistics*; Toole et al. (2021)

Table 2: Examples of research topics combining StanDat with complementary datasets.

6 Standardization and trade networks

This section showcases StanDat's applicability in providing new analyses by expanding on an important topic; that of standardization and trade. In doing so, the study follows up on the expanding literature on the effects of standards on trade (see e.g. Yang (2023)). Previous studies has found a generally positive relationship between adoption of international standards and trade (Knut Blind and Ramel 2018; Mangelsdorf 2011; Swann 2010). The positive relationship can be attributed to the fact that adopting a standard may signal openness, quality and safety to exporters, as well as enabling exporting countries to adapt their products to foreign markets (Clougherty and Grajek 2014). However, adopting an international standard is not without downsides – it can be costly, especially when an adopter has had little influence on the standardization process (Blind 2001).

This last observation shifts the question from the trade effect of *adopting* standards to the effect of *producing* standards. Büthe and Mattli (2011a) point out the importance of having influence in the standardization process, in particular how early participation in the standardization process allows countries to shape standards according to their needs. A growing literature has studied the factors explaining standardization involvement among firms (Blind 2006; Riillo 2013), and an emerging literature is investigating the involvement of national standards bodies in international standardization fora (Blind and von Laer 2022; Mattli and Büthe 2003). In particular, an advantage of participating in the standardization process for trade lies in the capacity to share knowledge efficiently and swiftly. Thus, joint participation in TCs may positively influence bilateral trade through several mechanisms; signalling openness to other countries, enhancing efficient and need-specific harmonization and enabling knowledge sharing within specific technologies.

Drawing inspiration from recent research in international relations that explores how networks reveal interdependence among international actors, this section investigates the relationship between joint TC membership and trade volumes through networks. International networks facilitate flow of resources like money, goods, or information, while also shaping and constraining the power of actors based on their connections and relative positions within these networks (Farrell and Newman 2019). Examining the correlation between standardization networks and trade networks

acknowledges the "complex interdependence" of networks, as highlighted by Keohane and Nye (1977). Researchers have investigated how trade networks interact with other networks such as migration (Sgrignoli et al. 2015), alliance building (Haim 2016), militarized conflict (Kinne 2012) and financial integration (Schiavo et al. 2010). These studies suggest that network constitutions in trade matters for the composition of other networks.

The global standardization network represents flow of information. Assuming that countries must both provide and receive information to reap the benefits of this network, the network consists of P-members connected by common TC membership, illustrated in figure 7. Each member body sends experts to their respective TCs, where the experts deliberate on producing standards that, in turn, regulate global interactions and transactions, one of them being trade[13].

Table 4 presents various models examining the relationship between a directed dyads' TC connections and bilateral trade[14]. Both dependent and independent variables are logged, reflecting the assumed declining utility of accumulating one extra unit of respectively TC connections and trade. The models rely on the gravity model (Salette and Tinbergen 1965) to control for trade confounders. Reflecting recent advances in the trade economics literature using the gravity model, the models utilize high-dimensional fixed effects, incorporating fixed effects on dyads, countries and years (Anderson 2011), a method recently used by for example (Carter and Poast 2020).

The models employ progressively more controls, detailed in 3, but with shorter time series. "Gravity" controls stem from the gravity model, targeting size and proximity. In the high-dimensional fixed effects specification, conventional Gravity controls such as GDP and capital distance are subsumed by the dyad fixed effects and country-year fixed effects. The "Gravity+R&D" model includes a measure of R&D intensity as patents per GDP. Since R&D intensity may be a mediator, the next models exclude this variable, but adds controls beyond the gravity framework. The "Gravity+" control set expands on "Gravity", including dyad regime similarity, preferential trade

[13]This measure is a proxy for participation, but it does not measure it directly. Formal participation in a TC does not always entail practical participation by the national member body's delegates (experts) (Alshadafan 2020).

[14]When constructing the network, countries participating in no shared TC are not mapped. Thus, using the Comtrade data as a baseline, dyads with missing TC connections were assumed to have no connection. Both measures are log transformed to reflect the assumed declining marginal benefit of one extra unit of TC membership or trade.

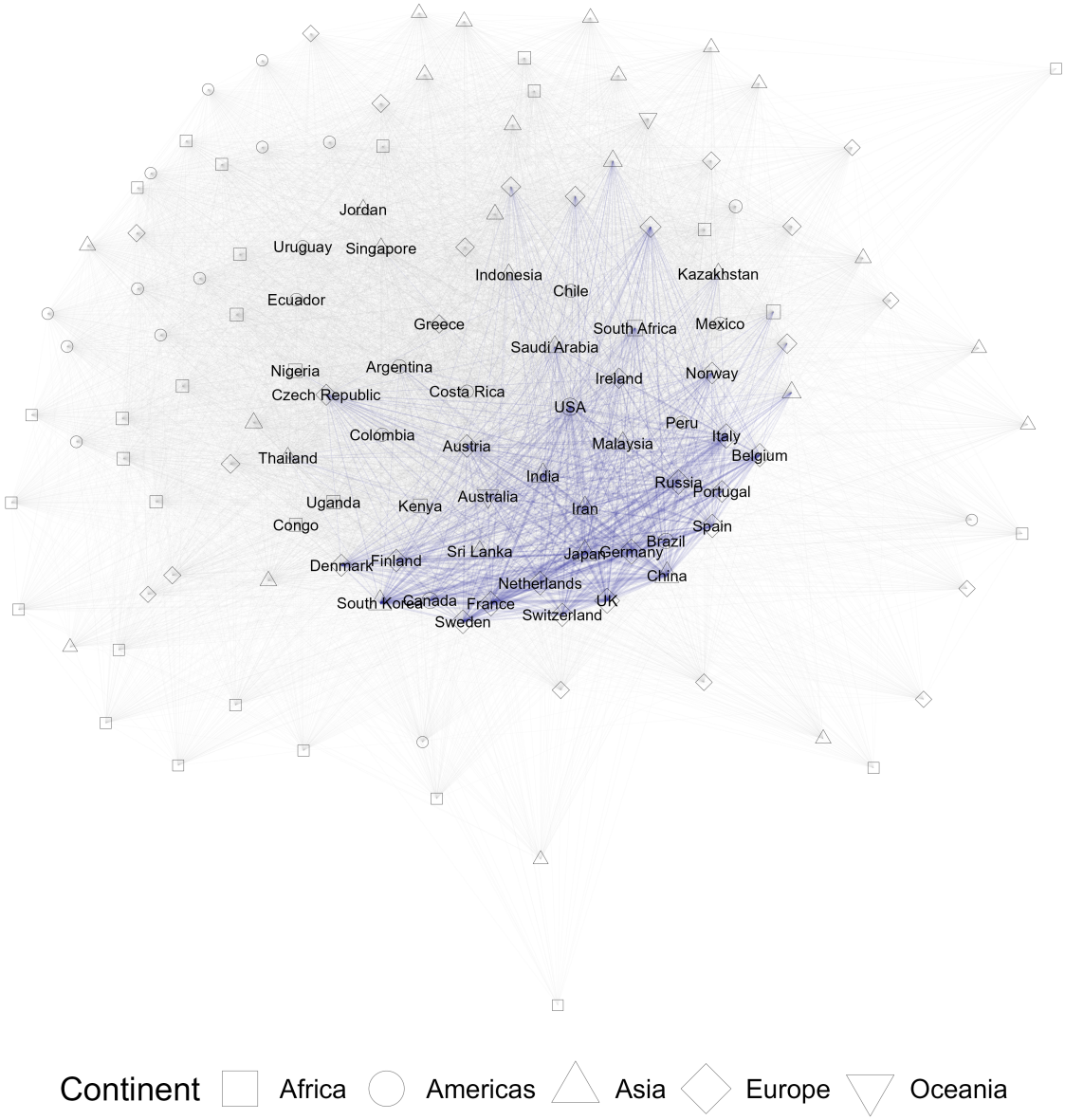


Figure 7: Countries sharing P-membership in technical committees, 2022. The size of the node indicates how many TCs the country participates in. A link between the nodes means that the countries participate in the same TCs. The size of the link indicates how many TC seats the countries share.

agreements (PTAs) and common currency. The "Gravity++" controls encompass the "Gravity+" controls plus indicators for neighboring states' strategic rivalry and engagement in alliances. Tables displaying coefficients of control variables can be found in Appendix table F9.

Table 4 shows patterns in alignment with previous findings regarding the positive relationship

Table 3: Control variables in table 4.

Model	Control variables	Source
Gravity	Regional trade agreement	CEPII Gravity Database (Conte et al. 2022)
	WTO member dyad	
Gravity+R&D	Patents as share of GDP	PatentsView (Toole et al. 2021)
Gravity+	Democratic dyad (polyarchy >0.4 = democratic)	Varieties of Democracy (Coppedge et al. 2024)
	Preferential trade agreements (PTA) in dyad	DESTA Database (Dür et al. 2014)
	Common currency	de Sousa (2012)
Gravity++	Alliance	Correlates of War (Gibler 2009)
	Strategic rivalry dyad	Miller (2019)

Table 4: Relationship between dyadic TC connections and trade volume.

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity+	Gravity++
ln(TC connections)	0.073***	0.084***	0.057***	0.036*	0.031
	(0.014)	(0.017)	(0.013)	(0.016)	(0.019)
Num.Obs.	402385	346684	229574	190173	125511
RMSE	1.38	1.38	1.26	1.25	1.14
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects by dyad, country and year, clustered standard errors by dyad and year.

Zero imputation on dyads with missing on TC connections.

Gravity controls: GDP, population, distance between capitals, common language, regional trade agreement, WTO dyad.

Gravity+R&D controls: Adds to Gravity patents per country.

Gravity+ controls: Adds to Gravity+ democratic dyad, preferential trade agreement, common currency.

Gravity++ controls: Adds to Gravity++ strategic rivalry, alliance.

between standardization and trade. Frequent TC connections correlate positively and significantly with trade. From the baseline model alone, increasing a dyad's TC connections by one percent is indicative of a seven percent increase in bilateral trade volumes. These results are mostly stable throughout various model specifications, including using alternative measures of trade, using a binary independent variable, and easing the fixed effect dimensionality to assess the restrictiveness of the model (see Appendix F).

However, three points should be made. First, the significantly positive coefficient becomes insignificant when adding the last set of control variables. Sensitivity checks suggests that this is not due to the shorter time series, indicating that the relationship may be partly driven by other

factors, such as the goodwill of democratic dyads or alliances (see Appendix table F18). Second, when controlling for R&D intensity, the TC coefficient remain significant and strong, suggesting that knowledge advantages gained from joint TC membership in terms of trade may operate partly through R&D intensity. However, this relationship is rather sensitive, as removing zero imputation on missing dyads from the standardization network renders the coefficient on "Gravity+R&D" insignificant (see Appendix table F16). Third, an importantly, although these models include multiple controls to account for possible confounders, the model cannot rule out reverse causality. For example, while information sharing could facilitate trade, large trade volumes may also incentivize countries to participate in the same TCs to influence standardization procedures. Robustness checks using GMM models indicate that there is no clear causal direction from joint TC membership to larger trade volumes (see Appendix table F19). However, a research approach designed for causal inference is necessary to delve deeper into this matter.

With these caveats in mind, the analysis nevertheless shows a rather strong relationship between TC connections and trade volumes, indicating that participating in standardization networks with other countries matter for bilateral trade. This relationship may partly stem from advantages in harmonizing expectations when countries have first-mover advantages in standardization, as noted by Büthe and Mattli (2011a). Further, countries may signal openness, safety and quality in trade by participating in standardization (Clougherty and Grajek 2014), and participation may enhance knowledge sharing, boosting R&D efforts and trade. Overall, this study supports the notion of complex interdependence in global markets, in which trade patterns seem to matter for a range of other network constitutions.

7 Conclusion

In the international political economy, standards are important regulatory tools, setting guidelines ranging from the size of containers to the definition of "quality". This paper aims to boost the growing literature on standards and standardization by presenting a new database, StanDat, constructed

from information provided by the International Standardization Organization (ISO). By doing so, this study also gives insight into the process of producing comprehensive databases when there is a lack of adequate data from other sources, countering availability bias on marginal topics in the social sciences (Mahrt and Scharkow 2013).

The StanDat database can be used by qualitative and quantitative scholars alike, either to produce descriptive statistics, assess scope conditions of previous findings, or contribute to new analyses. For example, by utilizing the StanDat database along with UN Comtrade data, this article finds support for the notion of complex interdependence in global markets, namely that countries which frequently participate in standardization processes together also trade more, although the causality of this relationship may go either way. Further examples of important questions encompass the legitimacy and efficiency of standards, or how standards relate to for example global inequality or climate change. Because of the interdisciplinary of the standardization literature, the StanDat database can be relevant for a wide set of scholars.

While the StanDat database is composed of ISO standards only, several other standardization organizations exist. The methodologies illustrated in this paper, encompassing data collection, organization, and dissemination, are applicable to these entities as well as numerous additional sources of data within the realm of social sciences. If data is publicly available on the internet, this paper demonstrates how to transform that into research data.

References

Abbott, K. W. and D. Snidal (2001). International 'standards' and international governance. *Journal of European Public Policy 8*(3), 345–370.

Alshadafan, A. F. (2020). Energy efficiency standards: The struggle for legitimacy. *International Journal of Standardization Research (IJSR) 18*(1), 1–17.

Anderson, J. E. (2011). The gravity model. *Annual review of economics 3*(1), 133–160.

Anderson, S. W., J. D. Daly, and M. F. Johnson (1999). Why firms seek iso 9000 certification: regulatory compliance or competitive advantage? *Production and operations management 8*(1), 28–43.

Anglin, K. L. (2019). Gather-narrow-extract: A framework for studying local policy variation using web-scraping and natural language processing. *Journal of research on educational effectiveness 12*(4), 685–706.

Arora, S. K., Y. Li, J. Youtie, and P. Shapira (2016). Using the wayback machine to mine websites in the social sciences: A methodological resource. *Journal of the Association for Information Science and Technology 67*(8), 1904–1915.

Baccini, L., A. Dür, and M. Elsig (2018). Intra-industry trade, global value chains, and preferential tariff liberalization. *International studies quarterly 62*(2), 329–340.

Baglioni, E., L. Campling, and G. Hanlon (2020). Global value chains as entrepreneurial capture: insights from management theory. *Review of international political economy : RIPE 27*(4), 903–925.

Bernstein, S. and B. Cashore (2007). Can non-state global governance be legitimate? an analytical framework. *Regulation governance 1*(4), 347–371.

Bijlmakers, S. (2023). *The International Organization for Standardization: A Seventy-Five-Year Journey toward Organizational Resilience*, pp. 261–286. Cambridge University Press.

Blind, K. (2001). The impacts of innovations and standards on trade of measurement and testing products: empirical results of switzerland's bilateral trade flows with germany, france and the uk. *Information economics and policy 13*(4), 439–460.

Blind, K. (2004). *The economics of standards: theory, evidence, policy*. Edward Elgar Publishing.

Blind, K. (2006). Explanatory factors for participation in formal standardisation processes: Empirical evidence at firm level. *Economics of innovation and new technology 15*(2), 157–170.

Blind, K. and A. Jungmittag (2008). The impact of patents and standards on macroeconomic growth: a panel approach covering four countries and 12 sectors. *Journal of productivity analysis 29*(1), 51–60.

Blind, K., M. Kenney, A. Leiponen, and T. Simcoe (2023). Standards and innovation: A review and introduction to the special issue. *Research Policy 52*(8), 1–9.

Blind, K. and M. von Laer (2022). Paving the path: drivers of standardization participation at iso. *The Journal of technology transfer 47*(4), 1115–1134.

Boeing, G. and P. Waddell (2017). New insights into rental housing markets across the united states: Web scraping and analyzing craigslist rental listings. *Journal of planning education and research 37*(4), 457–476.

Botzem, S. and L. Dobusch (2012). Standardization cycles: A process perspective on the formation and diffusion of transnational standards. *Organization Studies 33*(5–6), 737–762.

Braun, M. T., G. Kuljanin, and R. P. DeShon (2018). Special considerations for the acquisition and wrangling of big data. *Organizational research methods 21*(3), 633–659.

Brunsson, N. (2002). Organizations, markets, and standardization. In N. Brunsson and B. Jacobsson (Eds.), *A World of Standards*, pp. 21–39. Oxford University Press.

Brunsson, N., A. Rasche, and D. Seidl (2012). The dynamics of standardization: Three perspectives on standards in organization studies. *Organization Studies 33*(5-6), 613–632.

Büthe, T. and W. Mattli (2010, 02). International Standards and Standard-Setting Bodies. In *The Oxford Handbook of Business and Government*. Oxford University Press.

Büthe, T. and W. Mattli (2011a). *The New Global Rulers: The Privatization of Regulation in the World Economy*. New Jersey: Princeton University Press.

Büthe, T. and W. Mattli (2011b). Private nonmarket rule-making in context: A typology of global regulation. In *The New Global Rulers: The Privatization of Regulation in the World Economy*, pp. 18–41. Princeton University Press. Accessed 20 Mar. 2024.

Carter, D. B. and P. Poast (2020). Barriers to trade: How border walls affect trade relations. *International organization 74*(1), 165–185.

Cavallo, A. (2018). Scraped data and sticky prices. *The review of economics and statistics 100*(1), 105–119.

Chen, C. J., Y. Ding, and B. Xu (2014). Convergence of accounting standards and foreign direct investment. *The International Journal of Accounting 49*(1), 53–86.

Chow-Chua, C., M. Goh, and T. Boon Wan (2003). Does iso 9000 certification improve business performance? *International journal of quality & Reliability management 20*(8), 936–953.

Clougherty, J. A. and M. Grajek (2008). The impact of iso 9000 diffusion on trade and fdi: A new institutional analysis. *Journal of international business studies 39*(4), 613–633.

Clougherty, J. A. and M. Grajek (2014). International standards and international trade: Empirical evidence from iso 9000 diffusion. *International journal of industrial organization 36*, 70–82.

Conte, M., P. Cotterlaz, and T. Mayer (2022, July). The cepii gravity database. Working Paper 2022-05, CEPII.

Coppedge, M., J. Gerring, C. H. Knutsen, S. I. Lindberg, and e. a. Teorell (2024). V-Dem codebook v14. https://www.v-dem.net/data/the-v-dem-dataset/. Varieties of Democracy (V-Dem) Project.

Corbett, C. J. and D. A. Kirsch (2001). International diffusion of iso 14000 certification. *Production and operations management 10*(3), 327–342.

David, P. A. (1985). Clio and the economics of qwerty. *The American economic review 75*(2), 332–337.

de Sousa, J. (2012). The currency union effect on trade is decreasing over time. *Economics letters 117*(3), 917–920.

De Vries, H., K. Jakobs, T. M. Egyedi, M. Eto, S. Fertig, O. Kanevskaia, L. Klintner, C. Koch, I. Mijatovic, M. Mirtsch, et al. (2018). Standardization: Towards an agenda for research. *International Journal of Standardization Research (IJSR) 16*(1), 52–59.

Ding, J. (2024). The diffusion deficit in scientific and technological power: re-assessing china's rise. *Review of International Political Economy 31*(1), 173–198.

Dür, A., L. Baccini, and M. Elsig (2014). The design of international trade agreements: Introducing a new database. *The Review of International Organizations 9*(3), 353–375.

Eliantonio, M. and C. Cauffman (2020). *The Legitimacy of Standardisation as a Regulatory Technique: A Cross-disciplinary and Multi-level Analysis*. Cheltenham, UK: Edward Elgar Publishing.

Elken, M. (2017, March). Standardization of (higher) education in europe – policy coordination 2.0? *Policy and Society 36*(1), 127–142.

Farrell, H. and A. L. Newman (2019). Weaponized interdependence: How global economic networks shape state coercion. *International Security 44*(1), 42–79.

Frietsch, R. and U. Schmoch (2010). Transnational patents and international markets. *Scientometrics 82*(1), 185–200.

Gaffney, K. P., D. R. Hipp, M. Prammer, D. Kennedy, L. Brasfield, and J. M. Patel (2022). Sqlite: Past, present, and future. *Proceedings of the VLDB Endowment 15*(12), 3535–3547.

Gibler, D. M. (2009). *International Military Alliances, 1648-2008*. CQ Press.

Graham, B. A. T. and J. R. Tucker (2019). The international political economy data resource. *Review of International Organizations 14*(1), 149–161.

Graz, J.-C. (2019). *The Power of Standards: Hybrid Authority and the Globalisation of Services*. Cambridge University Press.

Haim, D. A. (2016). Alliance networks and trade: The effect of indirect political alliances on bilateral trade flows. *Journal of Peace Research 53*(3), 472–490.

Hallström, K. (2008). Iso expands its business into social responsibility. In M. Boström and C. Garsten (Eds.), *Organizing transnational accountability*, pp. 46–60. Edward Elgar Publishing.

Hallström, K. T. and W. Higgins (2010). International organization for standardization. In *Handbook of Transnational Economic Governance Regimes*, pp. 201–211. Brill Nijhoff.

Hallström, K. T. (2004). *Organizing International Standardization: ISO and the IASC in Quest of Authority*. Cheltenham: Edward Elgar.

Heikkilä, J., T. Ali-Vehmas, and J. Rissanen (2021). The link between standardization and economic growth: A bibliometric analysis. *International Journal of Standardization Research (IJSR) 19*(1), 1–25.

Heires, M. (2008). The international organization for standardization (iso). *New Political Economy 13*(3), 357–367.

Higgins, W. and K. T. Hallström (2007). Standardization, globalization and rationalities of government. *Organization 14*(5), 685–704.

Hu, Y.-H. and C.-F. Tsai (2022). An investigation of solutions for handling incomplete online review datasets with missing values. *Journal of experimental theoretical artificial intelligence 34*(6), 971–987.

Jackson, J. H. (1997). *The world trading system: Law and Policy of International Economic Relations* (2 ed.). MIT press.

Jansen, M. (2010). Developing countries, standards and the wto. *The journal of international trade economic development 19*(1), 163–185.

Keohane, R. O. and J. S. Nye (1977). *Power and Interdependence: World Politics in Transition*. Boston: Little, Brown & Co.

Kerwer, D. (2005). Rules that many use: Standards and global regulation. *Governance 18*(4), 611–632.

Kim, M. (2018). The "standard" in the gatt/wto tbt agreements: Origin, evolution and application. *Journal of World Trade 52*(5), 765–788.

Kim, M.-j., H. Lee, and J. Kwak (2020). The changing patterns of china's international standardization in ict under techno-nationalism: A reflection through 5g standardization. *International Journal of Information Management 54*.

Kinne, B. J. (2012). Multilateral trade and militarized conflict: Centrality, openness, and asymmetry in the global trade network. *The Journal of Politics 74*(1), 308–322.

Knut Blind, Axel Mangelsdorf, C. N. and F. Ramel (2018). Standards in the global value chains of the european single market. *Review of International Political Economy 25*(1), 28–48.

Krotov, V. and L. Johnson (2023). Big web data: Challenges related to data, technology, legality, and ethics. *Business Horizons 66*(4), 481–491.

Krotov, V., L. Johnson, and L. Silva (2020). Legality and ethics of web scraping. *Communications of the Association for Information Systems 47*, 539–563.

Lazer, D., A. Pentland, L. Adamic, S. Aral, A.-L. Barabasi, D. Brewer, N. Christakis, N. Contractor, J. Fowler, M. Gutmann, T. Jebara, G. King, M. Macy, D. Roy, and M. Van Alstyne (2009,

February). Social science. computational social science. *Science (New York, N.Y.) 323*(5915), 721—723.

Levinson, M. (2016). *The box: how the shipping container made the world smaller and the world economy bigger*. Princeton University Press.

Link, S. and E. Naveh (2006). Standardization and discretion: Does the environmental standard iso 14001 lead to performance benefits? *IEEE transactions on engineering management 53*(4), 508–519.

Loconto, A. and L. Busch (2010). Standards, techno-economic networks, and playing fields: Performing the global market economy. *Review of International Political Economy 17*(3), 507–536.

Louis, M. and C. Ruwet (2017). Representativeness from within: A comparison between the ilo and the iso. *Globalizations 14*(4), 535–549.

Luscombe, A., K. Dick, and K. Walby (2022). Algorithmic thinking in the public interest: navigating technical, legal, and ethical hurdles to web scraping in the social sciences. *Quality & Quantity 56*(3), 1023–1044.

Mahrt, M. and M. Scharkow (2013). The value of big data in digital media research. *Journal of Broadcasting & Electronic Media 57*(1), 20–33.

Mancini, M., P. Montalbano, S. Nenci, and D. Vurchio (2024, 02). Positioning in Global Value Chains: World Map and Indicators, a New Dataset Available for GVC Analyses. *The World Bank Economic Review*.

Manders, B., H. J. de Vries, and K. Blind (2016). Iso 9001 and product innovation: A literature review and research framework. *Technovation 48-49*, 41–55.

Mangelsdorf, A. (2011). The role of technical standards for trade between china and the european union. *Technology analysis strategic management 23*(7), 725–743.

Manovich, L. (2012). Trending: The promises and the challenges of big social data. In *Debates in the Digital Humanities* (NED - New edition ed.)., pp. 460. University of Minnesota Press.

Marx, A., M. Maertens, J. Swinnen, and J. Wouters (2012). Introduction: private standards and global governance. In A. Marx, M. Maertens, J. Swinnen, and J. Wouters (Eds.), *Private standards and global governance: Economic, legal and political perspectives*, pp. 5–8. Edward Elgar Publishing.

Mattli, W. (2001). The politics and economics of international institutional standards setting: an introduction. *Journal of European public policy. 8*(3), 328–344.

Mattli, W. and T. Büthe (2003). Setting international standards: Technological rationality or primacy of power? *World Politics 56*(1), 1–42.

Mena, S. and G. Palazzo (2012). Input and output legitimacy of multi-stakeholder initiatives. *Business Ethics Quarterly 22*(3), 527–556.

Miller, S. V. (2019). Create and extend strategic (international) rivalry data in r.

Murphy, C. and J. Yates (2009). *The International Organization for Standardization (ISO) global governance through voluntary consensus*. Routledge global institutions. London ;: Routledge.

Nadvi, K. (2008). Global standards, global governance and the organization of global value chains. *Journal of economic geography 8*(3), 323–343.

Narayanan, V. and T. Chen (2012). Research on technology standards: Accomplishment and challenges. *Research Policy 41*(8), 1375–1406.

Olsen, O. E. (2020). *Standardization and risk governance : a multi-disciplinary approach*. Routledge new security studies. London: Routledge.

Pauwelyn, J., R. Wessel, and J. Wouters (2012). *Informal international lawmaking*. Oxford University Press.

Peña, A. M. (2015). Governing differentiation: On standardisation as political steering. *European Journal of International Relations 21*(1), 52–75.

Prakash, A. and M. Potoski (2006). Racing to the bottom trade, environmental governance, and iso 14001. *American Journal of Political Science 50*(2), 350–364.

Riillo, C. A. F. (2013). Profiles and motivations of standardization players. *International journal of IT standards standardization research 11*(2), 17–33.

Ruwet, C. (2011). Towards a democratization of standards development? internal dynamics of iso in the context of globalization. *New global studies 5*(2), 1140–1140.

Rühlig, T. (2023). Chinese influence through technical standardization power. *The Journal of Contemporary China 32*(139), 54–72.

Salette, G. and J. Tinbergen (1965). Shaping the world economy. suggestions for an international economic policy. *Revue économique 16*(5), 840.

Sampaio, P., P. Saraiva, and A. Guimarães Rodrigues (2009). Iso 9001 certification research: questions, answers and approaches. *International Journal of Quality & Reliability Management 26*(1), 38–58.

Sampaio, P., P. Saraiva, and A. Guimarães Rodrigues (2011). Iso 9001 certification forecasting models. *The International journal of quality reliability management 28*(1), 5–26.

Schiavo, S., J. Reyes, and G. Fagiolo (2010). International trade and financial integration: a weighted network analysis. *Quantitative Finance 10*(4), 389–399.

Schmidtke, H., S. Schirmer, N. Krösche, and T. Lenz (2023, 05). The Legitimation of International Organizations: Introducing a New Dataset1. *International Studies Perspectives 25*(1), 86–110.

Sgrignoli, P., R. Metulini, S. Schiavo, and M. Riccaboni (2015). The relation between global migration and trade networks. *Physica A: Statistical Mechanics and its Applications 417*, 245–260.

Sletten, M. S. and I. T. Ellingsen (2020). When standardization becomes the lens of professional practice in child welfare services. *Child & Family Social Work 25*(3), 714–722.

Sommerer, T. and J. Tallberg (2016, 02). Transnational Access to International Organizations 1950–2010: A New Data Set1. *International Studies Perspectives 18*(3), 247–266.

Suarez, F. F. (2004). Battles for technological dominance: an integrative framework. *Research policy 33*(2), 271–286.

Swann, G. M. P. (2010). International standards and trade. *OECD* (97).

Timmermans, S. and S. Epstein (2010). A world of standards but not a standard world: Toward a sociology of standards and standardization. *Annual Review of Sociology 36*(1), 69–89.

Toole, A., C. Jones, and S. Madhavan (2021). Patentsview: An open data platform to advance science and technology policy.

Vastag, G. (2004). Revisiting iso 14000 diffusion: A new "look" at the drivers of certification. *Production and operations management 13*(3), 260–267.

Weitzel, T., D. Beimborn, and W. König (2006). A unified economic model of standard diffusion: The impact of standardization cost, network effects, and network topology. *MIS Quarterly 30*(3), 489–514.

Werle, R. and E. J. Iversen (2006). Promoting legitimacy in technical standardization. *Science, Technology & Innovation Studies 2*(1), 19–39.

Wiegmann, P. M., H. J. de Vries, and K. Blind (2017). Multi-mode standardisation: A critical review and a research agenda. *Research Policy 46*(8), 1370–1386.

Yang, L. (2023). The economics of standards: A literature review. *Journal of Economic Surveys n/a*(n/a).

Yarrow, D. (2022). Valuing knowledge: The political economy of human capital accounting. *Review of International Political Economy 29*(1), 227–254.

Zürn, M., A. Tokhi, and M. Binder (2021). The international authority database. *Global Policy 12*(4), 430–442.

Appendix: For Online Publication

Contents

A Codebook

StanDat Codebook

A database on international standards

Table of contents

Overview

StanDat consists of several datasets that covers several aspects of the landscape of international standards. The database is based on data from the International Standardization Organization (ISO). For more information on ISO, visit www.iso.org. For more information on the dataset, see this paper.

The database is categorized into 'Standards', 'TC-membership', 'Historical' and 'Certifications', each category with 2-3 datasets.

Category	Time series	Description	Source and method	Comments
Standards	1951 - 2023	Data on specific standards, including which technical committee that developed them, the life cycle of their production, year they were published, edition, number of pages, whether they have been withdrawn, abstract, sustainability goals and ICS code.	www.iso.org. With sublinks to every standard. Collected through webscraping using rvest.	The data has been subject to significant amounts of data cleaning.
TC-membership	2002/4 - 2023	Data on actors' membership in technical committees. There is one dataset on the countries (i.e. national member bodies) and one on the organizations in liaison.	Wayback Machine. Collected through webscraping using wayback, rvest and httr.	Because there is only a selection of snapshots of webpages in the archive, the data is incomplete. Imputation methods based on the collected data replaces for some of the missing values. The cells that have been imputed are indicated. The data has been subject to significant amounts of data cleaning.
Historical	1947 - 2015	Data on the historical development of ISO. One dataset includes membership in ISO over time, including type of membership and function of membership. One dataset shows when different technical committees were established.	Membership parsed from pdf. TC establishment scraped from iso.org and missing categories were categorized using ChatGPT.	The data has been subject to moderate amounts of data cleaning.
Certifications	1993 – 2020, but varies depending on ISO series.	Data on certifications of ISO standards. This includes data on the year of the survey, number of certificated provided by accredited certification bodies per country, industry and ISO standard series. The ISO Survey covers a selection of the ISO standard series. An overview of coverage and time series per coverage is given below.	The ISO Survey. The survey data is parsed from excel files.	From ISO: 'Every year we perform a survey of certifications to our management system standards. The survey shows the number of valid certificates to ISO management standards (such as ISO 9001 and ISO 14001) reported for each country, each year. [...] The ISO Survey is not a database. The providers of the data are the certification bodies accredited by IAF members and they participate on a voluntary basis. The level of participation fluctuates from one edition of the survey to another and can impact the survey results especially at the country level. Interpretations of the results and any conclusions on the trends should be made with these considerations in mind. The data has been subject to moderate amounts of data cleaning.

Standards

Coverage: 1951 - 2023

These datasets have standards as units, and gives information on when standards were published, the status of the standard, how large they are (in pages), which edition the standard is on, their International Classification for Standards code (ICS) (see https://www.iso.org/standards-catalogue/browse-by-ics.html), abstracts, sustainable developemnt goals that the standard fulfills, and the life cycle of the standard.

Status

Variable	Definition
stdno	Standard number
name	Name of the standard
year	Year the standard was published (standards under development are `NA`)
title	Name of TC the standard was developed within
committee	ID of the TC the standard was developed within
status	If the standard is withdrawn, deleted, developing or published
publication_date	When the standard was published (if published)
edition	The edition of the standard
pages	Number of pages of the standard
abstract	Abstract of the contents of the standard
ics_name	Name of the ICS code the standard is categorized into (canbe more than one)
ics_id	ID for the ICS code the standard is categorized into (can be more than one)
link	Link to the webpage where the information was scraped

SDGs

This dataset shows the **sustainable development goals** (SDGs) that each standard is reported to address (if any).

Variable	Definition
stdno	Standard number
name	Name of the standard
year	Year the standard was published (standards under development are `NA`)
title	Name of TC the standard was developed within

committee	ID of the TC the standard was developed within
sgd_number	Number of the sustainability goal that ISO reports the standard to contribute to (if any).
sdg_text	Name of the sustainability goal that ISO reports the standard to contribute to (if any).
link	Link to the webpage where the information was scraped

Life cycle

Process of stages for standard, as given by https://www.iso.org/stage-codes.html . The units of observation in this dataset is a life cycle stage for a given standard.

Variable	**Definition**
stdno	Standard number
name	Name of the standard
year	Year the standard was published (standards under development are `NA`)
title	Name of TC the standard was developed within
committee	ID of the TC the standard was developed within
life_stage	The stage reported in the life cycle of a given standard
life_stage_code	The code of the stage reported in the life cycle of a given standard
date	Date that the standard was at this life cycle stage
link	Link to the webpage the data was collected from

TC-membership

Coverage: 2002 - 2023

These datasets include information on the actors' membership in technical committees, i.e. that may participate in the production of standards. Standards are produced in various technical committees (TC) that are established based on demand from stakeholders, and proposed by national member bodies. To establish a technical committee, a member body sends a proposal which is then circulated among the other ISO members. At least five other member bodies have to vote in favor for the TC to be established. Those in favor take the role of P-members, and usually, the country responsible for the proposal takes the secretariat. Proposal drafts are often, in the first place, requests from other national actors.

Countries (national member bodies)

There are three member categories – full member, correspondent member and subscriber member. Only full members can become P-members (participating members) in TCs, and only P-members are able to participate actively in the technical work of the committee. Observing members are allows to follow the process but are not able to participate.

Variable	Definition
country	Country name
sdo	Name of main standardization developing organization in the country
year	Year of membership
committee	Number of TC
title	Name of TC
membership	Type of membership, either participating (P-member), observing (O-member), secretariat or twinned secretariat
impute	Whether memberships were imputed from the previous year
sector	The sector that ISO categorizes the TC into

Organizations (liaison)

Among organizations in liaison, there are four member categories, A, B, C and D, depending on how involved the organizations are in the standardization process.

Using the acronym is more reliable than using the name, as the name has been more often subject to change as webpages change.

Variable	Definition
acronym	Organization's acronym
name	Name of organization
year	Year of liaison
country	Country where the organization is located (fetched from address)
committee	Number of the committee that the organization was in liaison with
title	Name of the committee that the organization was in liaison with
type	Type of liaison for the given organization
impute	Whether the membership in given committee was imputed
sector	The sector that ISO categorizes the TC into

Historical

Coverage: 1947 - 2023

These datasets show the development of the International Standardization Organization over time in terms of members and technical committees.

Members

Shows membership in ISO over time. There are three types of membership; Participating member, Correspondent member and Subscriber member. Only P-members can participate actively in technical committees.

Variable	Definition
year	Year
country	Country
continent	Continent of country
membership_status	Which membership status the country had in the given year. U = No membership, M = membership, C = Correspondent member, S = Subscriber member.
membership_role	If there were any particular changes to the membership in the given year. with = Withdrawn, sus = Suspended, council = Council.

Technical committees

Technical committees have been established throghout ISO's history. This dataset includes some unknown missings, as some TCs have been established and then disbanded.

Variable	Definition
year	Year of establishment
title	Name of committee
committee	ID of committee
sector	The sector that ISO categorizes the TC into

Certifications

Coverage: Varying

The ISO Survey of Certifications is an annual survey of the number of valid certificates to ISO management system standards worldwide. The providers of data are the certification bodies accredited by the IAF MLA Members.

Disclaimer: The ISO Survey is not a database. The providers of the data are the certification bodies accredited by IAF members and they participate on a voluntary basis. The level of participation fluctuates from one edition of the survey to another and can impact the survey results especially at the country level. Interpretations of the results and any conclusions on the trends should be made with these considerations in mind.

Survey coverage for all datasets

Number of standard family	Name of standard family	Country coverage	Industry coverage
ISO 9001	Quality management systems	1993-2020	1998-2020
ISO 14000	Environmental management	1999-2020	1998-2020
ISO/IEC 27001	Information security management	2006-2020	2006-2020
ISO 50001	Energy management	2011-2020	2015-2020
ISO 22000	Food safety management	2007-2020	–
ISO 13485	Medical devices - Quality management systems	2004-2020	–
ISO 22301	Security and resilience	2014-2020	2014-2020
ISO/IEC 20000-1	Information technology	2015-2020	2015-2020
ISO 28000	Specification for security management systems for supply chains	2016-2020	2016-2020
ISO 39001	Road traffic safety (RTS) management systems	2016-2020	2016-2020

Country certifications

Variable	Definition
country	Country name

year	Year of survey
certificates	Number of certificates as provided by accredited certification bodies in the ISO Survey
iso	Code of ISO management standards series
iso_name	Name of ISO management standards series

Industry certifications

Variable	Definition
industry	Aggregate industry level
year	Year of survey
certificates	Number of certificates as provided by accredited certification bodies in the ISO Survey
iso	Code of ISO management standards series
iso_name	Name of ISO management standards series

Country and industry certifications

Variable	Definition
country	Country name
year	Year of survey
industry	Aggregate industry level
ISO 9001	Number of certificates within the ISO 9001 series
ISO 14001	Number of certificates within the ISO 9001 series
ISO/IEC 27001	Number of certificates within the ISO/IEC 27001 series

B Data gathering process

Please find the complete code to produce the StanDat database on Github.

Following the construction of these datasets, I used a SQLite database to host the data, a widely popular, functional and easy-to-use database (Gaffney et al. 2022). The storing process is easily integrated into the workflow using the *RSQLite* package and the database can be hosted as a file in cloud platforms such as OneDrive or Dropbox. Moreover, storing the dataset in a SQLite database, it is relatively straight-forward to construct a fast and simple user interface with *R Shiny*. Such applications increase accessibility to the data for less technical users, and it has the advantage of storing all information pertaining to the dataset in one place, including data coverage, variable definitions and codebook (see Appendix **??**). While developers are free to use any deployment method they want, deployment in *R Shiny* is made increasingly simple through RStudio's *shinyapps.io*, although costs can follow if the traffic becomes substantial.

Standards datasets

The procedure to construct the "Standards" datasets relied on webscraping. All standards produced are listed on ISO's current webpage, including the ones that are withdrawn or deleted. Thus, this scraping process utilized the current webpage of ISO only. The process involved three steps:

1. **Downloading the webpages** to a local folder. This was done by appending the strings "https://www.iso.org/standard/", [number], "?browse=tc". In order to catch all relevant standards, I iterated through all numbers from 1 to 150000, downloading when a webpage matching the url was found.

2. **Extracting and parsing information** from the webpages. This included finding the relevant nodes of the variables and fetching these into separate vectors, then cleaning the information. For this process, I used the R-package *rvest* and string operations, including regex, creating separate data tables for the life cycle and the general standards information.

3. **Gathering data** so that each separate datasets is can be merged into one long dataset, ensur-

ing compatibility across all datasets.

Participation datasets

The procedure to construct the "Participation" datasets relied on webscraping. ISO purchased the domain "www.iso.org" in late 2001, thus, 2002 is when the time series for the participation data starts. Using the Wayback Machine API through the Wayback R-package, this scraping process is composed of three steps. Because ISO changed their webpage four times in the period 2002 to 2023, step 1 and 2 had to be done four times with separate links and parsing processes. The four phases of ISO's webpages are:

- First version: 2002 - 2007
- Second version: 2008 - 2012
- Third version: 2013 - 2016
- Fourth version: 2017 - 2023

The three steps in making the Participation datasets were:

1. **Downloading the webpages** to a local folder. This was done by finding the url on member countries in ISO, which included a list of which technical committees they participate in. Then I used Wayback to find all snapshots of this webpage. All snapshots available were downloaded.
2. **Extracting and parsing information** from the webpage, i.e. finding relevant nodes in the webpage, extracting them, and then parsing the data to get a tidy format. This was done using the R-package *rvest* and general string operations (including regex).
3. **Cleaning the data.** This step is again composed of four steps:

(a) **General cleaning** to make all four datasets from step 1 and 2 compatible, including removing whitespace, removing special letters, ensuring that names of countries and organizations are compatible across the time series, replacing numbers/acronyms with names where relevant, etc.

(b) **Adding secondary information** from a different source of information. This was only done with the country dataset. While I have used the country-pages to construct the dataset, i.e. webpages for each member country where the technical committees they participate in are listed, another option is to use the webpages on technical committees, which lists the member countries participating. In this way, I can fill out information where a snapshot was not taken of a particular country in a particular year, by doing step 1 and 2 on the webpages for technical committees and use them to fill out missing data in the country dataset.

(c) **Imputing missing information.** Random missing values follow from the uneven snapshots of webpages taken by Wayback. A rule was followed to impute the missing values on the Participant datasets (see section C).

(d) **Removing duplicates.** After imputation, some countries might have been listed as being an X-member in a technical committee while this is not the case, i.e. false positives. This can be ruled out where a country is listed as both P-member and O-member, but one is an imputation. In other cases, there are duplicates even though there are no imputations, likely a case of countries switching membership during the year. In this case, the membership in year Y+1 is chosen as the correct membership type. Lastly, a very small bunch of countries were duplicated for no obvious reason – there were imputed with O-membership as this is more common than P-membership. For countries holding the Secretariat, these tended to also be listed as P-members. I include them only as Secretariat holders.

Historical datasets

The "Historical" datasets are gathered from a PDF file, the first page shown in figure B8. The PDF file was not machine-readable, so I ran it through Adobe to construct an excel file of the PDF file, then did some manual cleaning. In the next step, I read the excel file into R and parsed the data in order to produce a tidy format.

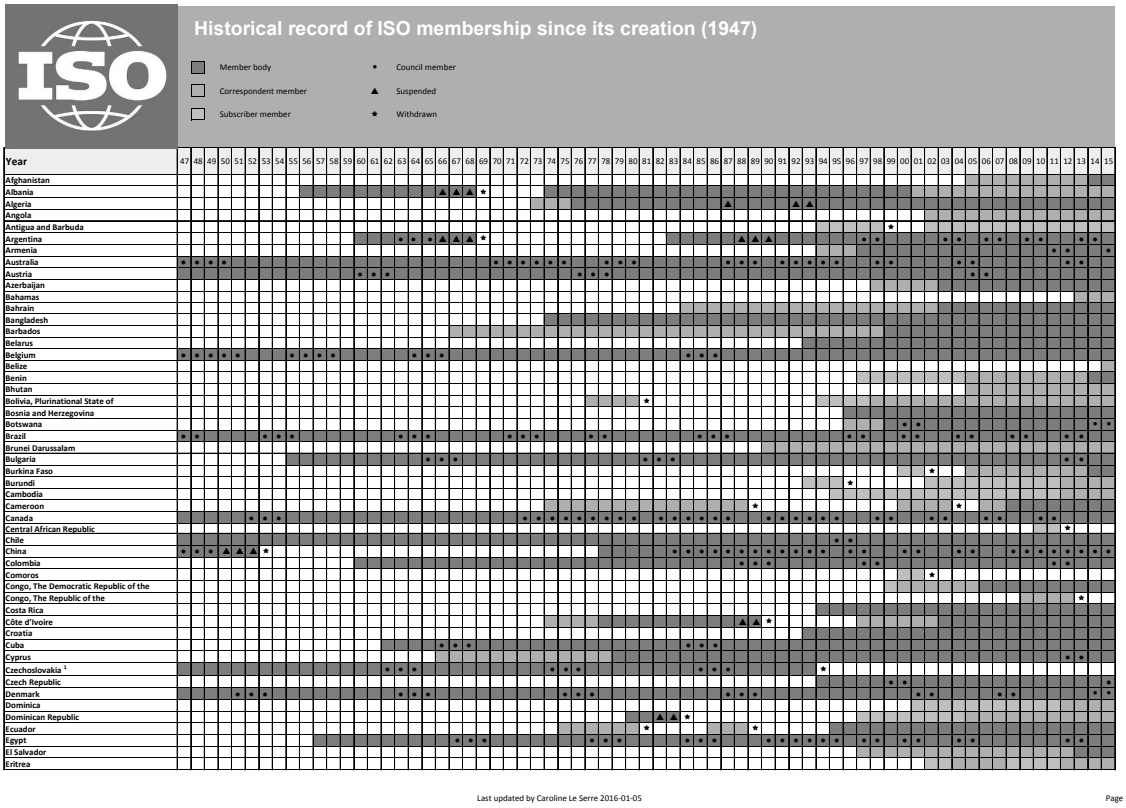


Figure B8: PDF file of historical membership in ISO.

Certification datasets

The "Certification" datasets are created from the ISO Survey. The ISO Survey is listed among ISO's public documents and are composed of several different excel files. The process thus included reading the excel files into R, parsing the data and cleaning to ensure consistency across years and make a tidy dataframe.

Per 2023, the surveys can be found at this link. The excel documents are composed of several sheets for each continent, and variously disaggregated by country, industry and country-industry over the years. Parsing thus ensures consistency as the datasets are gathered into three tidy dataframes - one for countries, one for industries and one for country-industries.

C Validation of the "TC-membership" datasets

For participation in technical committees for both countries (member bodies) and organizations (liaison), imputations have been made based on the following rule:

- If Country/Organization A has been an P-member in technical committee B in year Y-1 and Y+1, but year Y is missing, then impute for year Y that Country/Organization A is X-member of technical committee B.
- If Country/Organization A has been P-member in year Y+2 and O-member in year Y-2, then sequentially impute that A is O-member in Y-1, then P-member in Y+1, then O-member in Y, starting at the past values.
- If Country/Organization A is P-member in Y-1 but no other information is available, then do not impute anything.

This rule has the advantage of filling in space between two years where a country or organization is a member of a TC, but there are missing values in the middle. The rule is based on the assumption that missing values between two years of membership in the same TC are due to Wayback's uneven snapshot of webpages, and not due to the country or organization stepping out of the TC for the time period and then stepping back in. The assumption also holds that the country or organization switches membership halfway between two values if the membership type in Y-2 and Y+2 is different. While none of these assumptions are likely to hold true all the time, the validation below shows that the assumptions holds most of the time.

Face validity

Figure C9 and C10 show the amount of imputations for each country and organization over time. Separate files were made for each country and organization to view the imputations of TC membership and check for discrepancies. While face validity is a weak measure of validity in itself, it is a good first stage to gauge the validity of the imputations. The figures below show that the

amount of imputations for the countries and organizations are not extreme. Because the number of organizations is a lot higher than the number of countries, names on the Y-axis were removed in the organization plot. Separate files for each country and organization are available upon request and show the same patterns as figure C9 and C10.

For the remaining two validation procedures, the country dataset has been validated as access to country membership is more available than organizations in liaison. However, given that the two procedures of gathering data are similar, the validity results should hold for both the country dataset and the organization dataset.

Figure C9: Imputation of countries' participation in technical committees for Wayback data.

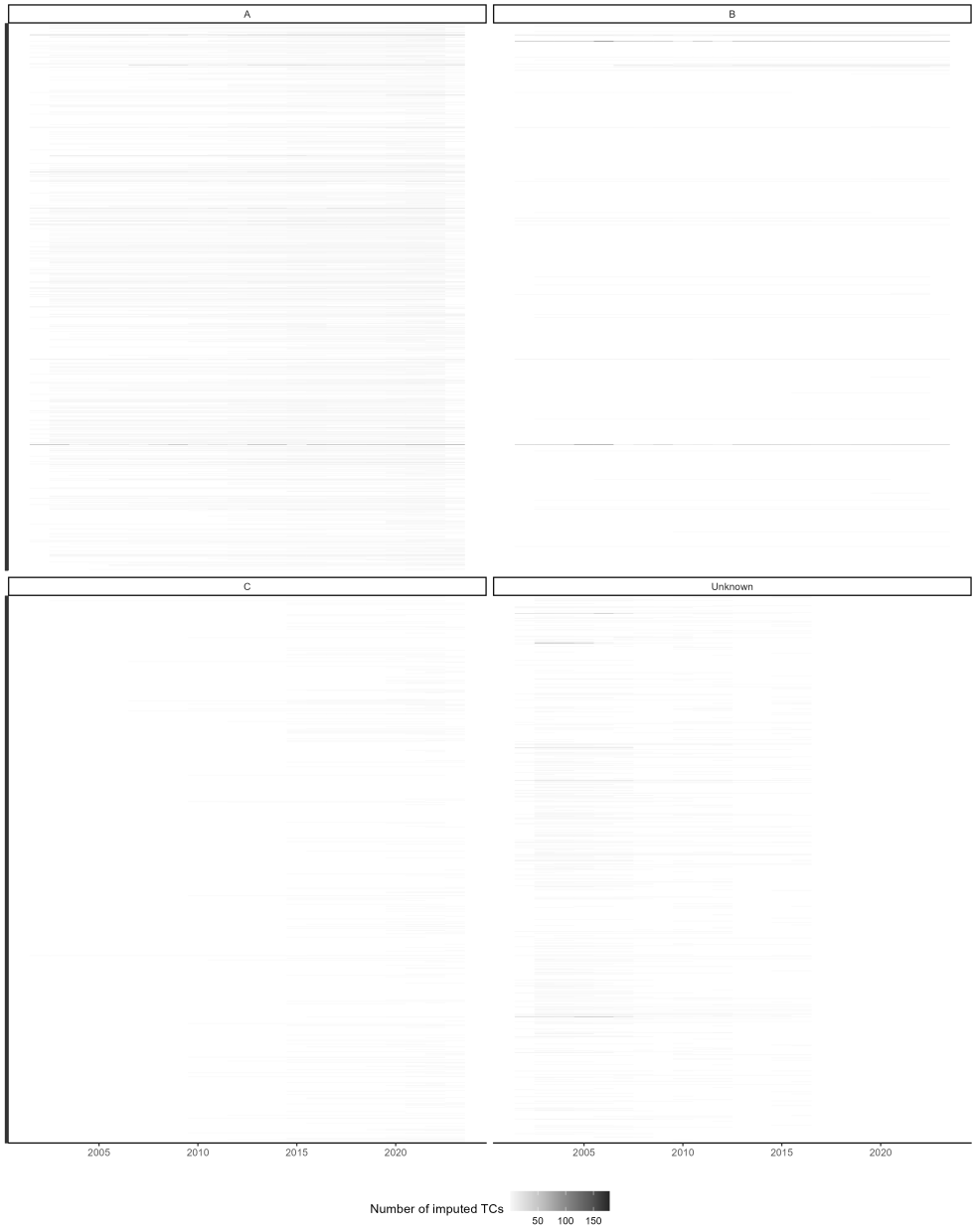


Figure C10: Imputation of organizations' participation in technical committees for Wayback data.

Validation against public documents

There are occasional documents on technical committees on the internet, for example public reports, papers or presentations prepared by the secretariat in relation to a meeting. I use a selection of five reports that I could find to validate the participation in various technical committees. These reports are:

- **2002:** A UN paper prepared for the *Eighth United Nations Conference on the Standardization of Geographical Names* from ISO/TC 211, Geographic Information Standards. Prepared by Olaf Østensen, Chairman ISO/TC 211 Geographic information/Geomatics, and Chairman, Joint Steering Group on Spatial Standardization and Related Interoperabiltiy (E/CONF.94/1).

- **2010:** A presentation prepared by Bob Page entitled "ISO Standards as a Contribution to Global Carbon Regimes (MRV)" for the 10th annual workshop on GHG training, specifically on TC 207.

- **2016:** A powerpoint presentation entitled "Report of the Secretariat of ISO/TC 34/SC 3 "Fruits and vegetables and their derived products". They list participants in TC 24/SC 3.

- **2016:** A paper entitled "Workplace air quality: International consensus standards" published in *J Occup Environ Hyg.* 13(7) by Eun Gyung Lee, Kevin Ashley, Dietmar Breuer, Michael J. Brisson, Martin Harper, and Christian Thom. They mention TC 146/SC 2.

- **2019:** A report prepared by Jouko Vaskimo entitled "ISO/TC 258, ISO Technical Committee for Project, Program, and Portfolio Management, convenes in Seoul, South Korea" published in PM World Journal. It lists participants in TC 258.

The results of the validation against these reports can be found in table C5. In general, the accuracy is above 80 percent. There are more false negatives in the beginning of the time series. Indeed, in 2002 there were only a few webpages to draw from and no imputations could be made,

as there were no previous years to infer from. In the latter part of the time series, the risk is larger for false positives, as imputations might have caused some countries to be erronously classified as participants (P-members or O-members) in a technical committee. However, the overall improvement in accuracy shows that the imputations usually are correct.

Table C5: Accuracy of StanDat based on checks against reports.

Technical committee	Year	Membership	False negative	False positive	Accuracy	Countries in committee
TC 211	2002	P-member	23	0	20.69	6
TC 211	2002	O-member	17	0	37.04	10
TC 207	2010	P-member	2	6	89.33	73
TC 207	2010	O-member	3	2	83.33	33
TC 146/SC 2	2016	P-member	0	0	100.00	23
TC 146/SC 2	2016	O-member	0	2	88.89	18
TC 34/SC 3	2016	P-member	1	1	91.67	23
TC 34/SC 3	2016	O-member	1	2	94.23	51
TC 258	2019	P-member	4	6	75.61	37
TC 258	2019	O-member	0	2	87.50	14

Validation against ANSI webpage - United States Secretariats

The United State standardization organization, ANSI, has comprehensive webpages. Using the Wayback Machine, I download ANSI's webpages showing US-held secretariats back to 2002. Figure C11 shows the secretariats that were listed in ANSI's webpages divided by whether they were captured in the StanDat database. In total, 1051 out of 1353 secretariats were captured throughout the timeseries, making an accuracy of 78,8. However, most of the missing secretariats are in the beginning of the time series, when data was scarce. Starting the time series from 2004 bumps the accuracy up to 85,8.

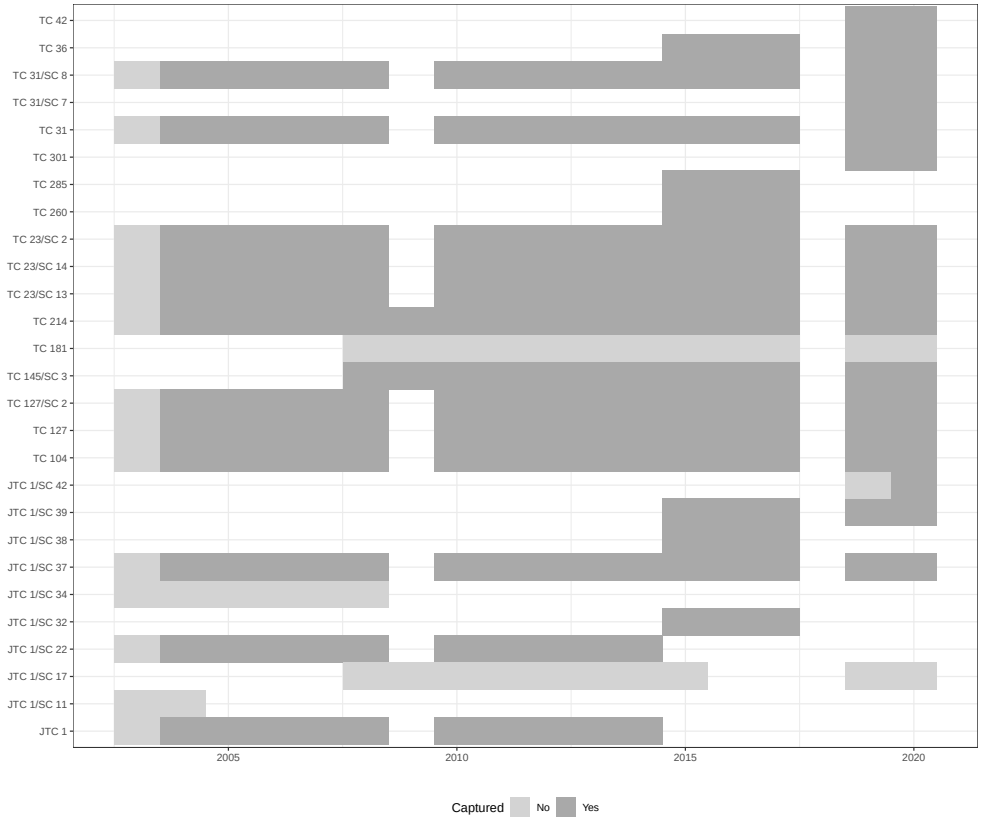
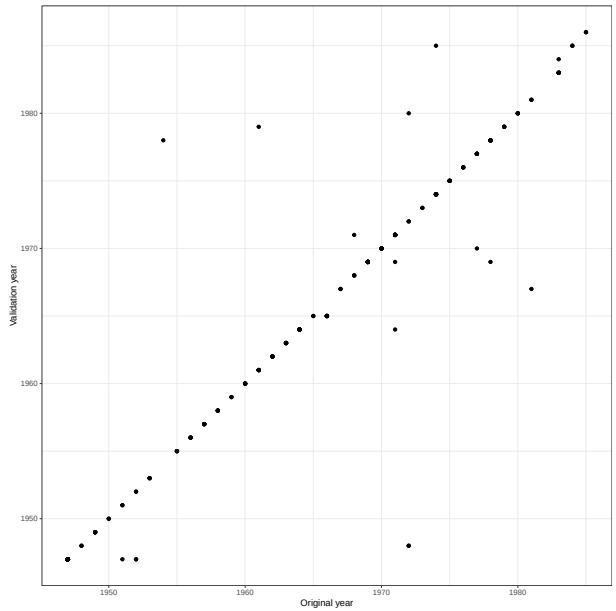


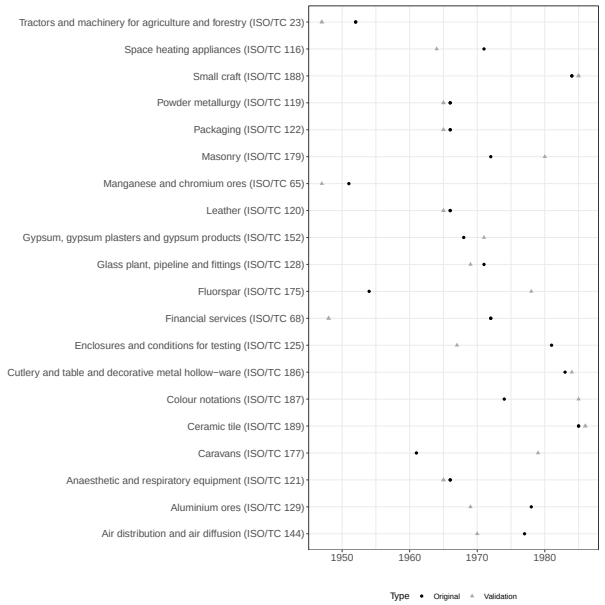
Figure C11: Secretariats listed at ANSI's webapges and captured in StanDat.

C.1 Validation of TC establishment

The dataset "TC establishment" under "Historical" was computed by extracting all technical committees ever reported both at ISO's webpage and from other sources. Then, to compute the year of establishment for sources that were not gathered through ISO, I use ChatGPT. This has the advantage of quickly computing the years for several TCs where the information is on the internet somewhere, without having to manually search for and add these years. However, the method is not without fault. Thus, here I validate the ChatGPT codings against a report from the U.S. Department of Commerce in 2000. The report contains a list of TCs and their establishment year. Of in total 1098 TCs in my dataset, the report mentions 296. Of these, 28 TCs were coded wrong. Of all the TCs, ChatGPT misses the mark by 0,14 years. Among the wrongly coded TCs, the average miss is 1,43 years. Table C12 gives an overview of the validation.



(a) Relationship between all TC establishment years in original dataset and validation dataset.



(b) Difference in year against the TCs where original and validation establishment year differs.

Figure C12: Validation of TC establishment year.

D Example of analysis assessing scope conditions of certifications

In 2001, Corbett and Kirsch (2001) published a study asking which factors that drive certification within the newly published ISO 14000 series on Environmental Management. Relying on interviews from practitioners, they hypothesized that variables such as a country's environmental orientation and previous certification in the older management standard series, ISO 9000 on Quality Management, would predict certification[15]. Using regression analysis, they found that more ISO 9000 certification (relative to GDP) is positively associated with more ISO 14000 certification (relative to GDP). Replicating this study using tree-based models, Vastag (2004) find similar patterns; ISO 9000 certification is an important predictor for ISO 14000 certification. A debate regarding the methodological choices ensued (Corbett and Kirsch 2004), but the data foundation was not discussed. This is understandable given the early date of these studies, where parsing the ISO Survey was possibly even more challenging, and few years were available to study. Their analysis stretches from 1993 to 1998, covering 63 countries. Using the StanDat database, I extend the analysis of Corbett and Kirsch (2001) to 230 countries over 28 years, and also include another ISO series; ISO/IEC 27001 on Information Security Management Systems. I use a fixed effects linear regression model employing many of the same control variables as Corbett and Kirsch (2001), and cluster the standard errors by country-year.

Table D6 shows the models. The first model reaffirms the patterns found by Corbett and Kirsch (2001) and Vastag (2004), even when extending the sample and including fixed effects, certification in ISO 9001 is significantly positively associated with certification in ISO 14001. However, as shown in the next two models, the association between ISO 9001 certification and ISO 14001 certification is weaker, and only previous certification within ISO 14001 is significantly and positively associated with ISO/IEC 27001 certification. This implies that the similarity between ISO 9000 and ISO 14000 found by Corbett and Kirsch (2001) does only partly extend to ISO/IEC 27001,

[15]Corbett and Kirsch (2001) study certification within the complete ISO 9000 series, not only the main standard ISO 9001. Yet, the series on Quality Management is mainly represented by ISO 9001 and Environmental Management by ISO 14001, which is why I refer to ISO 9001 and ISO 14001 in this article.

implying that the drivers or certification infrastructure may differ more between ISO/IEC 27001 and the other two. As pointed out by Fomin et al. (2008) when suggesting some explanations for a low adoption rate of ISO/IEC 27001 compared to ISO 9001, the latter often brings relatively clear benefits such as improved market share and reduced costs, while the first aims to prevent security failures and to mitigate their consequences, where the benefit is less obvious in a day-to-day practice.

However, the findings could partly be explained by the time difference between the publication of ISO 9001 (1993) and ISO/IEC 27001 (2006), which means that by the time ISO/IEC 27001 was introduced, many organizations were already ISO 9001 certified many years ago. Given the longer time series, this is something to take into account in the new models. Table D7 gives some credibility to this notion, showing that when using the *cumulative* number of certification as a share of GDP, ISO 9001 and ISO 14001 are both significantly and positively associated with ISO/IEC 27001 certification[16]. As such, this simple analysis may bring a humble addition to the literature on some of the most popular ISO series; ISO/IEC 27001, ISO 14001 and ISO 9001 (Culot et al. 2021; Heras-Saizarbitoria and Boiral 2013). More generally, this brief analysis shows how the StanDat database can help scholars extend analyses to a wider population, as well as investigating whether relationships found for one specific standard series holds for other series.

[16]Carry-over counts from previous years when counting the cumulative numbers of certifications leads to a slightly higher number of observations in table D7 than in table D6.

Table D6: Relationship between certification in T-1 and T for various ISO series.

	Dependent variable: Certifications		
	ISO 14001	ISO 27001	ISO 27001
Certification in ISO 9001 (1 year lag)	0.160**	0.009	−0.011*
	0.042	0.006	0.004
Certification in ISO 14001 (1 year lag)			0.101***
			0.020
GDP per capita	209.847	4.504	7.461
	153.321	14.408	10.676
Exports per GDP (ln)	0.218***	0.062**	0.036**
	0.056	0.016	0.009
Industry value added (% of GDP)	−0.004*	−0.001	0.000
	0.002	0.000	0.000
Num.Obs.	3769	2321	2321
RMSE	0.24	0.04	0.03
Time series	1999-2022	2006-2022	2006-2022

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table D7: Relationship between cumulative certification in T-1 and T for various ISO series.

	Dependent variable: Certifications		
	ISO 14001	ISO 27001	ISO 27001
Cumulative certification in ISO 9001 (1 year lag)	0.023***	0.024***	0.001
	0.003	0.005	0.005
Cumulative certification in ISO 14001 (1 year lag)			0.088***
			0.015
GDP per capita	−39.572	192.486	95.479
	50.684	120.404	66.618
Exports per GDP (ln)	0.053	0.027	0.012
	0.031	0.033	0.025
Industry value added (% of GDP)	0.001	0.001	0.001+
	0.001	0.001	0.001
Num.Obs.	3771	2738	2738
RMSE	0.21	0.14	0.12
Time series	1999-2022	2006-2022	2006-2022

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

E Example of analysis on standardization and patents

Much research has been conducted on the role of standards in innovation. One question entails whether standards have a positive or negative effect on innovation, finding that under certain conditions, standardization seems to enhance innovation (Acemoglu et al. 2012; Allen and Sriram 2000; Blind et al. 2017). There are indications suggesting a similar phenomenon with ISO standards as well (Manders et al. 2016), though there remains a need for further research examining cross-country variations in innovation and ISO certification (Lim and Prakash 2014; Mentel and Hajduk-Stelmachowicz 2020).

Yet another question asks not whether the adoption of standards enhances innovation, but whether standardization may be a goal for innovators. This question probes the motives of standardizers in enhancing patented technology, and may in fact be one of the reasons why countries want to participate in TCs (Blind and von Laer 2022). Many scholars have studied the role of standard-essential patents (SEP), i.e. when patented technology becomes an essential part of a standard (Lerner and Tirole 2015). However, the relationship between patented technology and participating in standardization is difficult to quantify, as studies suggest that there is a significant overdeclaration of SEPs, while at the same time, only a subgroup of patented technology relevant to a standard is usually reported (Depoorter et al. 2019). Thus, scholars have been working on other ways of mapping patents to standards (Baron and Pohlmann 2018; Brachtendorf et al. 2023).

One approach could be to map patent classification (IPC) to TCs. In this small illustration on exploring the relationship between standardization and innovation, I follow that approach. This example focuses on ICT technology, a fast-paced technology area where the role of standardization for innovation has been particularly questioned (Teece 2018). Using a detailed concordance table in an OECD report (Inaba and Squicciarini 2017), I map standards on ICT technology to ISO/IEC JTC 1, the most general TC within information technology. In doing this, I merge StanDat's TC-membership dataset with data on patents registered at the United States Patent and Trademark Office (USPTO) (Toole et al. 2021) by country-year[17]. The question is whether being part of this

[17]While there may be bias in data gathered from national patent offices, since application and granting processes

major TC within ICT is associated with more patent output in that technology area[18]. Patents are measured in fractional counts (Blind and von Laer 2022; Frietsch and Schmoch 2010).

The analysis in table E8 shows that membership in ISO/IEC JTC 1 is significantly associated with a larger output of patents within ICT technology. For example, for the United States in 2015, the estimated number of ICT patents if the country was not a member would be 6200, compared to an estimated 15400 upon being a member of ISO/IEC JTC 1. While the model includes country-year fixed effects, the direction of the causal effect may go both ways – innovation activity can lead to TC membership, and TC membership may enhance innovation activity. Interestingly, this relation is not distinguishable for P-members or O-members, indicating that being active in the process does not equate more patents – merely observing the negotiations might suffice.

vary (Frietsch and Schmoch 2010), the USPTO database has been found to be among the most reliable in terms of quantifying innovation activity (Kim and Lee 2015). Another advantage of this database is that it contains very recent data, allowing for long time series.

[18]The technology area includes high speed network, mobile communication, digital security, sensor and device network, high speed computing, large capacity high speed storage, cognition and meaning understanding, human interface, imaging and sound technology, information communication devices, electronic measurement, and a residual category.

Table E8: Relationship between membership in ISO/IEC JTC 1 and number of ICT patents.

	Dependent variable: Number of ICT patents	
	TC membership	Type of membership
Membership in TC	0.905**	
	0.339	
P-member in TC		0.324
		0.223
GDP per capita	0.000	0.000
	0.000	0.000
Industry value added (% of GDP)	−0.061*	−0.063*
	0.028	0.028
ICT % of service exports	0.038*	0.038*
	0.016	0.016
Num.Obs.	1107	936
RMSE	679.85	739.16
Time series	2004-2022	2004-2022

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects: Country and year.

Clustered standard errors by country and year.

Model: Poisson.

F Robustness checks for Table 4

Table 4 showing control variables.

Table F9 shows all control variables for the main analysis.

Table F9

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity+	Gravity++
ln(TC connections)	0.073***	0.084***	0.057***	0.036*	0.031
	(0.014)	(0.017)	(0.013)	(0.016)	(0.019)
Patents (exporter) as share of GDP			−0.013**		
			(0.003)		
Patents (importer) as share of GDP			−0.005**		
			(0.001)		
Regional trade agreement		−0.040	−0.093*	−0.069	−0.125+
		(0.042)	(0.040)	(0.041)	(0.056)
WTO dyad		−0.122**	−0.169**	−0.073	−0.112
		(0.040)	(0.044)	(0.061)	(0.110)
Democratic dyad				−0.002	0.008
				(0.026)	(0.027)
Preferential trade agreement				0.020	0.016
				(0.045)	(0.039)
Common currency				−0.172*	−0.178*
				(0.072)	(0.073)
Alliance					−0.022
					(0.076)
Strategic rivals					0.037
					(0.070)
Num.Obs.	402 385	346 684	229 574	190 173	125 511
RMSE	1.38	1.38	1.26	1.25	1.14
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects by dyad, country and year, clustered standard errors by dyad and year.

Zero imputation on dyads with missing on TC connections.

Table 4 using trade flow data from IMF

Table 4 made use of trade date from UN Comtrade. Table F10 shows that results are quite similar when using trade data from IMF instead, although this results in less data points, as the IMF data ends in 2020. The last two models give quite weak and insignificant coefficients, indicating that states' goodwill towards each other, measured in terms of democratic dyad, preferential trade agreements or common currency, may account for some of the effect of joint TC membership on trade.

Table F10

	Dependent variable: ln(Dyadic trade) (IMF).				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
ln(TC connections)	0.051**	0.053**	0.035**	0.004	−0.016
	0.014	0.014	0.011	0.015	0.020
Patents (exporter) as share of GDP			−0.013***		
			0.003		
Patents (importer) as share of GDP			−0.008*		
			0.003		
Regional trade agreement		−0.072	−0.099*	−0.073	−0.129*
		0.045	0.043	0.045	0.053
WTO dyad		−0.053	−0.083+	−0.071	−0.125
		0.042	0.043	0.047	0.082
Democratic dyad				0.009	0.001
				0.032	0.029
Preferential trade agreement				0.004	0.002
				0.050	0.046
Common currency				−0.154*	−0.135
				0.068	0.074
Alliance					−0.053
					0.059
Strategic rivals					0.022
					0.084
Num.Obs.	298 659	298 659	205 630	181 238	118 944
RMSE	1.29	1.29	1.18	1.18	1.07
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2020	2004-2020	2004-2020	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects: Dyad, country and year.

Clustered standard errors by dyad and year.

Zero imputation on dyads with missing on TC connections.

Table F11

	Dependent variable: Share of trade				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
ln(TC connections)	0.00029*	0.00030*	0.00042*	0.00050*	0.00064*
	0.00012	0.00012	0.00016	0.00018	0.00024
Patents (exporter) as share of GDP			−0.00002+		
			0.00001		
Patents (importer) as share of GDP			0.00000		
			0.00000		
Regional trade agreement		0.00043*	0.00052*	0.00052*	0.00062*
		0.00016	0.00020	0.00019	0.00022
WTO dyad		−0.00011	−0.00011	0.00013	0.00033
		0.00022	0.00026	0.00035	0.00019
Democratic dyad				−0.00004	−0.00004
				0.00005	0.00005
Preferential trade agreement				0.00032	0.00014
				0.00045	0.00035
Common currency				−0.00010	0.00003
				0.00019	0.00021
Alliance					0.00233
					0.00148
Strategic rivals					−0.00518+
					0.00254
Num.Obs.	402385	346684	229574	190173	125511
RMSE	0.01	0.01	0.01	0.01	0.01
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects: Dyad and year.

Clustered standard errors by dyad and year.

Zero imputation on dyads with missing on TC connections.

Table 4 using share of trade as dependent variable

Table 4 used as the dependent variable the total trade between countries in a given year (log transformed). Some scholars, e.g. Blind and von Laer (2022), use share of trade instead. Table F11 shows that the results are robust to such a specification.

Table F12

	Dependent variable: Presence of TC membership (binary) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
Presence of TC connection	0.147***	0.177***	0.159***	0.137**	0.085+
	(0.031)	(0.038)	(0.029)	(0.033)	(0.041)
Patents (exporter) as share of GDP			−0.013**		
			(0.003)		
Patents (importer) as share of GDP			−0.005**		
			(0.001)		
Regional trade agreement		−0.037	−0.096*	−0.069	−0.124+
		(0.043)	(0.041)	(0.039)	(0.056)
WTO dyad		−0.116*	−0.169**	−0.072	−0.110
		(0.041)	(0.045)	(0.062)	(0.110)
Democratic dyad				−0.001	0.008
				(0.027)	(0.027)
Preferential trade agreement				0.018	0.016
				(0.045)	(0.039)
Common currency				−0.202*	−0.191*
				(0.072)	(0.078)
Alliance					−0.018
					(0.076)
Strategic rivals					0.031
					(0.070)
Num.Obs.	402 385	346 684	229 574	190 173	125 511
RMSE	1.38	1.38	1.26	1.25	0.01
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Fixed effects: Dyad and year.
Clustered standard errors by dyad and year.

Table 4 using a dichotomous independent variable

While the quantity of TC connections may be meaningful, another question is if sharing a TC membership in itself goes together with more trade. Table F12 shows that using TC membership as a dichotomous variable does not alter results.

Table 4 using country fixed effects

Table 4 used a rigorous high-dimensional fixed effects model which can be quite restrictive. Table F13 shows that the coefficients remain significant in the same direction when loosening up the fixed effects model by only controlling for country-year.

Table F13

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
ln(TC connections)	0.490***	0.383***	0.248***	0.149**	0.026
	(0.053)	(0.051)	(0.049)	(0.041)	(0.041)
Patents (exporter) as share of GDP			−0.015*		
			(0.005)		
Patents (importer) as share of GDP			−0.005*		
			(0.002)		
Regional trade agreement		2.105***	1.954***	2.362***	1.564***
		(0.149)	(0.151)	(0.157)	(0.140)
WTO dyad		0.371*	0.164	0.408*	0.752*
		(0.146)	(0.112)	(0.184)	(0.239)
Democratic dyad				0.193*	0.109
				(0.076)	(0.068)
Preferential trade agreement				0.823**	0.432+
				(0.227)	(0.225)
Common currency				1.125*	0.419
				(0.394)	(0.406)
Alliance					1.877***
					(0.154)
Strategic rivals					1.426*
					(0.499)
Num.Obs.	402 385	346 684	229 574	190 173	125 511
RMSE	2.57	2.51	2.34	2.34	2.21
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects: Country 1, country 2 and year.

Clustered standard errors by country 1, country 2 and year.

Zero imputation on dyads with missing on TC connections.

Table 4 using region fixed effects

In testing for an even less rigorous restriction, table F14 shows that the results hold also when controlling for region-year.

Table F14

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
ln(TC connections)	1.416***	1.263***	1.274***	1.076***	1.061***
	(0.052)	(0.037)	(0.065)	(0.038)	(0.037)
Patents (exporter) as share of GDP			−0.046		
			(0.029)		
Patents (importer) as share of GDP			−0.007		
			(0.004)		
Regional trade agreement		1.366**	1.434**	1.847***	1.423**
		(0.327)	(0.276)	(0.281)	(0.282)
WTO dyad		0.975**	0.431*	0.374*	0.413+
		(0.225)	(0.142)	(0.129)	(0.184)
Democratic dyad				−0.053	−0.052
				(0.147)	(0.116)
Preferential trade agreement				0.547+	0.216
				(0.240)	(0.143)
Common currency				0.924	0.505
				(0.588)	(0.631)
Alliance					1.198*
					(0.393)
Strategic rivals					1.940*
					(0.662)
Num.Obs.	399046	344892	229574	190173	125511
RMSE	3.27	3.22	3.02	3.10	3.06
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects: Region for country 1, region for country 2 and year.

Clustered standard errors by region for country 1, region for country 2 and year.

Zero imputation on dyads with missing on TC connections.

Table 4 using 5-year period fixed effects

The results in table F15 further tests for over-controlling by using dyad-period-fixed effects. The results hold to this specification.

Table F15

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
ln(TC connections)	0.121**	0.145**	0.083**	0.073*	0.069
	(0.022)	(0.028)	(0.017)	(0.020)	(0.039)
Patents (exporter) as share of GDP			−0.014		
			(0.007)		
Patents (importer) as share of GDP			−0.009+		
			(0.003)		
Regional trade agreement		−0.084	−0.161+	−0.024	−0.162
		(0.080)	(0.063)	(0.041)	(0.080)
WTO dyad		−0.077	−0.132	−0.097	−0.039
		(0.089)	(0.097)	(0.098)	(0.112)
Democratic dyad				−0.064	0.004
				(0.052)	(0.047)
Preferential trade agreement				0.050	0.036
				(0.057)	(0.077)
Common currency				−0.225*	−0.302*
				(0.070)	(0.063)
Alliance					−0.026
					(0.094)
Strategic rivals					−0.028
					(0.197)
Num.Obs.	127945	99013	59849	70600	51975
RMSE	1.18	1.17	1.05	1.06	0.91
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Fixed effects: Region for dyad and 5-year period.
Clustered standard errors by dyad and 5-year period.
Zero imputation on dyads with missing on TC connections.

Table 4 without zero imputation on dyads with missing on TC connection

Table 4 had imputations of zero on dyads that sported no TC connection. This is because when constructing a network, dyads with no edge will not be included in the dataset. Since the ISO webpage lists all countries that participate in TCs, it is natural to assume that they have no TC connection when this is missing. Table F16 runs the regression without imputations. The main results remain, except that the coefficient when controlling for R&D intensity becomes insignificant, as mentioned in the article.

Table F16

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
ln(TC connections)	0.059***	0.063***	0.029+	0.082**	0.060+
	(0.013)	(0.014)	(0.015)	(0.020)	(0.028)
Patents (exporter) as share of GDP			−0.014**		
			(0.004)		
Patents (importer) as share of GDP			−0.012**		
			(0.004)		
Regional trade agreement		−0.024	−0.026	−0.060	−0.176+
		(0.034)	(0.031)	(0.049)	(0.085)
WTO dyad		−0.135+	−0.167*	−0.095	−0.097
		(0.075)	(0.075)	(0.091)	(0.115)
Democratic dyad				−0.026	0.016
				(0.032)	(0.035)
Preferential trade agreement				0.010	0.010
				(0.049)	(0.045)
Common currency				−0.060	−0.060
				(0.061)	(0.061)
Alliance					−0.008
					(0.076)
Strategic rivals					−0.016
					(0.083)
Num.Obs.	176 104	148 518	129 778	81 490	46 951
RMSE	1.05	1.06	0.99	0.94	0.84
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects: Dyad and year.

Clustered standard errors by dyad and year.

Table 4 with patents data from the World Intellectual Property Organization (WIPO)

The models in table 4 used data from PatentsView, which is based on data from the U.S. Patent & Trademark Office (USPTO). While USPTO is found to be the most appropriate patent database for studies on global innovation patterns (Kim and Lee 2015). However, as with any national registration office, it may be biased towards domestic residents or likewise. Therefore, table F17 illustrates how the results in models in table 4 are consistent using patent data from WIPO instead of USPTO.

Table F17

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity+	Gravity++
ln(TC connections)	0.073***	0.084***	0.056***	0.036*	0.031
	(0.014)	(0.017)	(0.011)	(0.016)	(0.019)
Patents (exporter) as share of GDP			0.000		
			(0.001)		
Patents (importer) as share of GDP			−0.001		
			(0.001)		
Regional trade agreement		−0.040	0.004	−0.069	−0.125+
		(0.042)	(0.028)	(0.041)	(0.056)
WTO dyad		−0.122**	−0.082	−0.073	−0.112
		(0.040)	(0.060)	(0.061)	(0.110)
Democratic dyad				−0.002	0.008
				(0.026)	(0.027)
Preferential trade agreement				0.020	0.016
				(0.045)	(0.039)
Common currency				−0.172*	−0.178*
				(0.072)	(0.073)
Alliance					−0.022
					(0.076)
Strategic rivals					0.037
					(0.070)
Num.Obs.	402385	346684	141426	190173	125511
RMSE	1.38	1.38	1.02	1.25	1.14
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects by dyad, country and year, clustered standard errors by dyad and year.

Zero imputation on dyads with missing on TC connections.

Table 4 with only Gravity controls, but same time series

The models in table 4 had a smaller time series when including control variables, due to the availability of data. To check whether the results might be driven by smaller time series rather than the inclusion of the extra control variables, table F18 shows models with shorter time series without the given control variables. The coefficient for TC connections is significant and positive across specifications, indicating that the coefficient is rendered insignificant in the primary models due to the control variables, and not the shorter time series.

Table F18

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity	Gravity
ln(TC connections)	0.073***	0.084***	0.057***	0.071**	0.056*
	(0.014)	(0.017)	(0.013)	(0.017)	(0.021)
Patents (exporter) as share of GDP			−0.013**		
			(0.003)		
Patents (importer) as share of GDP			−0.005**		
			(0.001)		
Regional trade agreement		−0.040	−0.093*	−0.174**	−0.228**
		(0.042)	(0.040)	(0.055)	(0.055)
WTO dyad		−0.122**	−0.169**	−0.071	−0.085
		(0.040)	(0.044)	(0.051)	(0.093)
Num.Obs.	402385	346684	229574	228249	150324
RMSE	1.38	1.38	1.26	1.29	1.18
Controls	No	Gravity	Gravity+R&D	Gravity	Gravity
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed effects by dyad, country and year, clustered standard errors by dyad and year.

Zero imputation on dyads with missing on TC connections.

Table 4 using a Generalized Methods of Moments model

The Generalized Method of Moments (GMM) models are often used for dynamic panel data where the number of groups is smaller than the time series, when the researcher wants to control for endogeneity. Because GMM models allows the moments conditions to exceed the number of parameters, the researcher can include lagged dependent variables as internal instruments along with lagged dependent variables as regressors, essentially controlling for the persistence of the dependent variable (Arellano and Bond 1991). This technique, though not immune to critique given its reliance on a set of strong assumptions, remains widely adopted by numerous researchers, particularly those within the field of economics, as a means to elucidate causal relationships when the dependent variable exhibits high persistence. In this specification, I use the System GMM estimator, as this has been shown to be more robust for unbalanced panels than the difference estimator (Blundell and Bond 1998).

Because the inclusion of time dummies sometimes creates a singular matrix which prevents the estimation, the second and third model incorporates only dyad-fixed effects. While many of the models do show a significant coefficient for TC connections, the direction of the coefficient varies. Moreover, only the Gravity++ model has remotely valid instruments, according to the Sargan-Hansen test[19]. In this model, the coefficients for TC connections are invalid, leading to the conclusion that there is no clear indication that causality goes from joint TC membership to larger trade volumes.

[19]Neither the model Gravity++, not any of the other models, actually pass the Sargan-Hansen test, having p-values above 0.05. This is typical for models with a high number of observations, and may not necessarily mean that the instruments are invalid (Kiviet and Kripfganz 2021), but should still be considered a weakness.

Table F19

	Dependent variable: ln(Dyadic trade) (UN Comtrade)				
	Baseline	Gravity	Gravity+R&D	Gravity++	Gravity+++
Lag ln(Dyadic trade), 1	0.524***	0.638***	0.654***	0.181*	0.634***
	(0.006)	(0.004)	(0.004)	(0.091)	(0.010)
Lag ln(Dyadic trade), 2	0.237***	0.339***	0.377***	0.104***	0.366***
	(0.005)	(0.004)	(0.004)	(0.024)	(0.009)
ln(TC connections)	0.156***	0.082***	−0.049***	−0.008	0.011
	(0.009)	(0.010)	(0.011)	(0.013)	(0.016)
Lag ln(TC connections), 1	0.137***	−0.052***	−0.022*	−0.015	−0.030*
	(0.009)	(0.009)	(0.009)	(0.012)	(0.013)
Regional trade agreement		0.090***	−0.104***	0.040	−0.030+
		(0.012)	(0.008)	(0.038)	(0.015)
WTO dyad		0.393***	−0.247***	0.084+	0.003
		(0.032)	(0.026)	(0.046)	(0.012)
Patents (exporter) as share of GDP			−0.006***		
			(0.001)		
Patents (importer) as share of GDP			−0.003***		
			(0.000)		
Democratic dyad				0.038	−0.029**
				(0.025)	(0.009)
Preferential trade agreement				0.016	0.034+
				(0.016)	(0.019)
Common currency				0.008	−0.083***
				(0.041)	(0.018)
Alliance					0.004
					(0.019)
Strategic rivalry					0.067
					(0.043)
Num.Obs.	409627	473328	327762	82757	103584
Controls	No	Gravity	Gravity+R&D	Gravity+	Gravity++
Time series	2004-2022	2004-2021	2004-2021	2004-2015	2004-2011
Fixed effects	Dyad & Year	Dyad	Dyad	Dyad & Year	Dyad & Year
Sargan-Hansen p-value	< 2.22e-16	< 2.22e-16	< 2.22e-16	0.003	4.3781e-11
Autocorrelation test (2) p-value	< 2.22e-16	< 2.22e-16	< 2.22e-16	< 2.22e-16	< 2.22e-16

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Clustered standard errors by dyad and year.

Model: Generalized Methods of Moments (GMM)

Appendix references

Acemoglu, D., G. Gancia, and F. Zilibotti (2012). Competing engines of growth: Innovation and standardization. *Journal of economic theory 147*(2), 570–601.e3.

Allen, R. H. and R. D. Sriram (2000). The role of standards in innovation. *Technological forecasting social change 64*(2), 171–181.

Arellano, M. and S. Bond (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *The review of economic studies 58*(2), 277–297.

Baron, J. and T. Pohlmann (2018). Mapping standards to patents using declarations of standard-essential patents. *Journal of economics management strategy 27*(3), 504–534.

Blind, K., S. S. Petersen, and C. A. Riillo (2017). The impact of standards and regulation on innovation in uncertain markets. *Research policy 46*(1), 249–264.

Blind, K. and M. von Laer (2022). Paving the path: drivers of standardization participation at iso. *The Journal of technology transfer 47*(4), 1115–1134.

Blundell, R. and S. Bond (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics 87*(1), 115–143.

Brachtendorf, L., F. Gaessler, and D. Harhoff (2023). Truly standard-essential patents? a semantics-based analysis. *Journal of economics management strategy 32*(1), 132–157.

Corbett, C. J. and D. A. Kirsch (2001). International diffusion of iso 14000 certification. *Production and operations management 10*(3), 327–342.

Corbett, C. J. and D. A. Kirsch (2004). Response to "revisiting iso 14000 diffusion: A new "look" at the drivers of certification". *Production and operations management 13*(3), 268–271.

Culot, G., G. Nassimbeni, M. Podrecca, and M. Sartor (2021). The iso/iec 27001 information security management standard: literature review and theory-based research agenda. *TQM journal 33*(7), 76–105.

Depoorter, B., P. Menell, and D. Schwartz (2019). *Research Handbook on the Economics of Intellectual Property Law*. Research Handbooks in Law and Economics series. United Kingdom: Edward Elgar Publishing.

Fomin, V. V., H. Vries, and Y. Barlette (2008). Iso/iec 27001 information systems security management standard: exploring the reasons for low adoption.

Frietsch, R. and U. Schmoch (2010). Transnational patents and international markets. *Scientometrics 82*(1), 185–200.

Heras-Saizarbitoria, I. and O. Boiral (2013). Iso 9001 and iso 14001: Towards a research agenda on management system standards. *International journal of management reviews : IJMR 15*(1), 47–65.

Inaba, T. and M. Squicciarini (2017). Ict: A new taxonomy based on the international patent classification.

Kim, J. and S. Lee (2015). Patent databases for innovation studies: A comparative analysis of uspto, epo, jpo and kipo. *Technological forecasting social change 92*, 332–345.

Kiviet, J. F. and S. Kripfganz (2021). Instrument approval by the sargan test and its consequences for coefficient estimation. *Economics Letters 205*, 109935.

Lerner, J. and J. Tirole (2015). Standard-essential patents. *Journal of Political Economy 123*(3), 547–586.

Lim, S. and A. Prakash (2014). Voluntary regulations and innovation: The case of iso 14001. *Public administration review 74*(2), 233–244.

Manders, B., H. J. de Vries, and K. Blind (2016). Iso 9001 and product innovation: A literature review and research framework. *Technovation 48-49*, 41–55.

Mentel, U. and M. Hajduk-Stelmachowicz (2020). Does standardization have an impact on innovation activity in different countries? *Problems and perspectives in management 18*(4), 486–503.

Teece, D. J. (2018). Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. *Research policy 47*(8), 1367–1387.

Toole, A., C. Jones, and S. Madhavan (2021). Patentsview: An open data platform to advance science and technology policy.

Vastag, G. (2004). Revisiting iso 14000 diffusion: A new "look" at the drivers of certification. *Production and operations management 13*(3), 260–267.