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Technical measures, Environmental protection, and Trade

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Abstract

Technical regulations are numerous, growing, and less transparent than price measures. Frequently used for Non-trade Policy Objectives (NTPOs), the technical regulations are adopted also for environmental protection. The trade effects of environmental measures are underinvestigated. Relying on a unique and original dataset of technical measures notified for environmental reasons, we show how they hinder bilateral trade flows, and tend to favour trade flows of countries with solid economic and political influence, such as high-income and G20 economies. Regardless of the environmental impacts of the technical regulations, beyond the scope of our investigation, the measures shape trade in favour of the wealthiest and most industrialised countries which have better financial and technical endowments to comply with environmentally friendly requirements. Far from suggesting which mechanism drives the discriminatory nature, we argue that the rapid raise of new regulations for the environmental protection may exacerbate existing divide.

Keywords

International trade; Non-trade policy objective; Technical regulation; TBT.

JEL Codes

F13, F18, O24.

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Declarations of Interest

None

1. Introduction

Protecting the environment is a global goal that governments are trying to pursue through diverse interventions. For instance, the (price-based) Carbon Border Adjustment Mechanism levies duties on the carbon content of imports (e.g., Kortum and Weisbach, 2016); cooperative agreements, such as the Emissions Trading System in the European Union and the Waxman-Markey Bill in the United States[1], cap the amount of greenhouse gases that can be emitted, granting tradable emissions allowances[2] (e.g., Meng, 2017; Verde and Borghesi, 2022); standards and technical measures (i.e., non-tariff measures –NTMs–) are also imposed to regulate environmental issues.

The contribution of NTMs to the environment-related debate is underinvestigated (exception made for relevant papers such as Fontagné et al., 2005a, Fontagné et al., 2005b, and Shapiro, 2021). Technical measures are a relevant class of NTMs (UNCTAD, 2019) based on non-cooperative and non-price-based mechanisms: they are designed for trade and (to enforce commitments on) non-trade policy objectives, such as the environmental protection (e.g., Borchert et al., 2021; Ferrari et al., 2021). The technical measures may have positive or negative impacts on trade, either favouring trade among countries and firms capable of complying with the technical measures, or raising trade costs, thus limiting the market access to partners (and firms) with lower capabilities.

We use a unique and comprehensive dataset of notifications on technical measures, classified by objectives, to disentangle the effects of the environment-related technical measures. Information on the Technical Barriers to Trade (TBT)[3] are provided by the Information Management System (IMS) of the World Trade Organisation (WTO). The econometric estimations are based on a theoretically based gravity model (e.g., Costinot and Rodriguez-Clare, 2014; Head and Mayer, 2014), and allow us to comment on the heterogeneous effects of the technical measures. Understanding the effects of the environment-related technical measures, which are rapidly increasing in number and relevance, is important to level the playing field of the policy debate on internationally coordinated efforts to lower the anthropogenic impacts on the environment.

This study is relevant for at least three reasons. First, technical measures are numerous and growing (UNCTAD-WB, 2018): the share of trade regulated by environmental technical measures boosted from 3 percent (in 2010) to 16 percent (in 2020), with an increase in monetary terms of about 2 trillion USD in a decade. Furthermore, the number of traded products, regulated by environmental technical measures, has increased exponentially, from about 600 products (in 2010) to more than 2,000 products (in 2020)[4]. Second, technical measures are more and more frequent in sensitive sectors (e.g., agri-food sector) and in labour-intensive sectors (Dal Bianco et al., 2016; de Melo and Nicita, 2018a) and are less transparent than pricing mechanisms. Third, technical measures have heterogenous effects, which are difficult to quantify (Gourdon et al., 2020; Beghin and Schweizer, 2021), and cannot be classified a priori as detrimental measures for trade (Cadot et al., 2018).

The extant literature on NTMs (e.g., Santeramo and Lamonaca, 2019; Disdier and Fugazza, 2020; Beverelli et al., 2022) suggests three sources of heterogeneities: (i) implementing and affected countries, (ii) products under regulation, (iii) types of measures. For instance, technical measures tend to hinder trade from less developed countries (e.g., Disdier et al., 2008; Kee et al., 2009), and to have positive (and proportionally increasing) effects on trade of countries with higher income levels (e.g., Bao and Qiu, 2012; Bratt, 2017). Non-manufacturing sectors (e.g., agriculture and food industries, crude materials, and mineral fuels) tend to be more impeded by technical measures than

1 The actual Emissions Trading System, set up in 2005, is the world's first international emissions trading system. The proposed but not active Waxman-Markey Bill is an energy bill of 2009 that would have established a variant of an emissions trading plan following the Emission Trading System of the European Union.

2 The cap is reduced over time to progressively cut total emissions. The emissions allowances are available in a limited number to ensure them a value.

3 The focus here is on TBT due to their broader coverage and direct link with environment-related issues.

4 Data are from the WTO TBT IMS and the *Base pour l'Analyse du Commerce International* (BACI) of the *Centre d'Études Prospectives et d'Informations Internationales* (CEPII).

manufacturing sectors (e.g., chemicals, manufacturing, machinery), as documented by the meta-analysis of Li and Beghin (2012) and by empirical analyses (e.g., Moenius, 2004; Beghin et al., 2016; Ghodsi et al., 2017; Niu et al., 2018). The mixed effects of technical measures are also due to the type of measure being implemented and to the non-trade policy objective addressed. For instance, Schlueter et al. (2009) found a pro-trade effect of measures addressing the protection of animal health, while Fontagné et al. (2005b) conclude on the negative effects of the environmental measures on food trade and on their positive effects on trade of manufactured goods.

The environmental targets, such as emission standards or air quality standards[5], are also correlated with country-specific factors, such as the level of economic development (e.g., Copeland et al., 2022) or the placement in the geopolitical scenario (e.g., Nordhaus, 2015; Nordhaus, 2021). The rationale is simple. The environmental targets can be achieved by modifying the production processes and orienting the industries toward clean techniques (e.g., Copeland and Taylor, 1994; Bao and Qiu, 2012). On the other hand, the demand for cleaner products is correlated with per-capita income and level of economic development (e.g., Fontagné et al., 2005a; de Melo and Solleder, 2020) as explained by the environmental Kuznets curve, and associated with the type and quality of institutions, as well as to the political orientation of the governance[6] (e.g., Nordhaus, 2020; Nordhaus, 2021; Hoekman and Wolfe, 2023). The differences across countries can be explained either from the consumer perspectives, as the demand for clean goods correlates with the level of income, and from the producer side, insofar greener technologies are more widely adopted in developed economies (e.g., Bao and Qiu, 2012). The divide that the trade regulations may exert on trading countries is well recognised by the WTO: the article 12.4 of the WTO TBT Agreement regulates special and differential treatments for developing countries[7], to balance the comparative advantage of developed exporters in complying with the technical and financial requirements subsumed into the technical measures (e.g., Hoekman and Holmes, 1999).

Against the above-described framework, the contribution of our manuscript to the extant debate is at least three-fold. First, from a methodological perspective, we exploit the informative content of technical measures notified under the WTO TBT Agreement using a rich dataset consisting of more than one hundred countries and all tradable goods. We isolate the technical measures notified to address exclusively the protection of the environment, so as to minimise the effects of confounding factors induced by multiple non-trade policy objectives. Second, from an empirical perspective, we show the regularities (and the mixed evidence) of the trade effects of environmental measures: while the average effect on trade is negative, we describe multiple heterogeneities across countries and sectors. Moreover, we show that the environmental measures favour trade among countries with similar macroeconomic features or geopolitical connections (e.g., high income countries, members of the Group of 20 (G20), industrialised countries, and countries with similar environmental standards). Third, we feed the policy debate on climate clubs with empirical evidence from a trade-

5 The reference here is not to requirements imposed by technical measures (e.g., product standards, standards related to processes), but to any targets related to the environment, such as emission standards, air quality standards (e.g., Copeland et al., 2022). Environmental technical measures and environmental targets differ by actors and mechanisms involved. The ability to comply with requirements imposed by technical measures is directly related to the level of technology adoption which depends on the decisions of single producers (e.g., Farrokhi and Pellegrina, 2023). Differently, the adoption of environmental targets is affected by specific interests at the domestic level (e.g., public opinion, lobbying activities) and depends on the priorities set by governments (e.g., Hoekman and Wolfe, 2023).

6 For instance, like-minded countries tend to target similar environmental goals. A relevant example is the Like Minded-Group of Developing Countries (LMDC), representing more than 50 percent of the world's population, organised as a block negotiator in international organisations such as the United Nations (UN) and the WTO (e.g., Narlikar and Odell, 2006). As for the environmental targets, several groups are worth mention: the Group of 77 (G-77) developing countries founded in 1964 in the setting of the UN Conference on Trade and Development (UNCTAD); the African Group of Negotiators (African Group) established in 1995 at COP1 in Berlin as an alliance of African member states; the Environmental Integrity Group (EIG) and the Umbrella Group, two coalitions between selected countries; the 27 members of the European Union which have private meetings to agree on common negotiating positions; the Arab States comprised of 22 member states; the Small Island Developing States (SIDS), a coalition of some 40 low-lying islands; the group of 46 Least Developed Countries which regularly work together in the UN system.

7 Developing countries are allowed to implement technical regulations consistent with the indigenous technologies and production methods and processes for products of special trade interest to them (e.g., Hoekman and Nicita, 2018).

based perspective. Nordhaus (2015) offers the idea of climate clubs as a potential solution to the free-riding problem originated by the provision of global public goods. Climate club would foster the adoption of effective interventions (e.g., carbon tax, cap-and-trade) among participating countries, and legitimate the imposition of penalties (e.g., higher tariffs) to nonparticipants. We postulate that the technical measures should be a set of potential interventions to be adopted by like-minded countries (e.g., high income countries, members of the G20, big emitters, countries with high levels of environmental quality, countries notifying environmental measures).

The rest of the paper is structured as follows. In Section 2, we synthesised the debate on technical regulations and international trade, and present some stylised facts on the environmental measures. Section 3 and 4 report, respectively, the econometric identification strategy to isolate the trade effects, and the empirical findings, along with robustness checks and sensitivity analyses. We treat the endogeneity issues potentially correlated with reverse causality and self-selection and depict the sources of heterogeneity in trade effects. The article's contributions and the implications for the scientific and policy debates are synthesised in Section 5.

2. Environmental measures and trade

2.1. Current debate

The general tendency of reduction of tariff levels, which are currently below 5 percent on average, is coupled with the raise of behind-the-border measures (UNCTAD-WB, 2018), such as the technical measures notified under the WTO SPS and TBT Agreements[8] (de Melo and Nicita, 2018a) and applied to both domestically produced and imported goods to achieve trade and non-trade policy objectives (Hoekman and Nicita, 2018; Borchert et al., 2021; Ferrari et al., 2021). Ralf Peters, chief of the Trade Information Section in the Trade Analysis Branch of UNCTAD, noted that "[technical measures] have become more salient in international trade, […] are used increasingly for trade and non-trade objectives, and impact all areas of our lives – social, environmental and economic." (UNCTAD, 2018).

The effect of environmental measures on trade is ambiguous (Fontagné et al., 2005b). Complying with environmental measures informs consumers in the importing (implementing) country on the environmental quality of traded goods: technical measures overcome asymmetric information issues (Beghin et al., 2015; Cadot and Gourdon, 2016) and this, in turn, may increase the demand for imports leading to a 'trade catalyst effect'. On the other hand, complying with environmental measures imposes additional costs: firms need to adapt their production and sale process to fulfil new requirements (Fontagné et al., 2015; Adarov and Ghodsi, 2023); the increase in marginal costs shrinks the export capacity, leading to a 'trade barrier effect'. Let us elaborate more on these mechanisms. Suppose that a technical measure (covering environmental issues) is notified under the TBT Agreement. At the domestic level, it may increase marginal costs and shrink the domestic supply; moreover, it may expand the domestic demand, insofar the asymmetric information on the environmental quality of the good is partially resolved. These shifts in market fundamentals raise the autarky price, and (in open economies) the import price would increase as well (e.g., Bratt, 2017): the (net) effects on imports would depend on the comparative advantage of the foreign producers in terms of capability to comply with the new regulation (e.g., Marette and Beghin, 2007; Beghin et al., 2012). Put differently, the imports will increase (i.e., 'trade facilitation effect') if the requirements of technical measures are fulfilled with a relatively lower effort in the exporting countries. On the

8 While SPS measures are mainly related to food safety issues of the implementing country, TBT are technical regulations, standards, testing and certification procedures, aiming to promote standards of human health and safety, environmental protection, consumer information, or quality. TBT regulate aspects connected to public goods, such as the environment, and therefore have rules that cover territorial and extra-territorial issues. The WTO Agreements on the application of SPS measures (i.e., WTO SPS Agreement) and of TBT (i.e., WTO TBT Agreement) aims to ensure these measures are notified according to the non-trade policy objectives they pursue, while avoiding unnecessary obstacles to trade. For the remainder of the paper, we refer to the technical measures (TBTs) notified under the WTO TBT Agreement.

contrary, if domestic producers have a comparative advantage in complying with the measures, or with the legal procedures, trade will be lower.

Following the abovementioned rationale, despite environmental measures are multilateral, their effects are heterogenous across trade routes. For instance, consider the trade relationships between the United States and both China and Argentina, after the United States has implemented a new environmental measure. If exporters from China are capable to comply with the environmental measure, the Chinese exports are likely to increase, whereas the Argentinean exporters (if not able to comply with the regulation) would be disfavoured. Besides the effects on the existing trade routes, the environmental measures may also favour trade creation or trade diversion effects (e.g., Mattoo et al., 2022).

Which trade effects would prevail? As mentioned earlier, the effects on trade are likely to be quite heterogeneous across countries and sectors.

The trade effects of the environmental measures are likely correlated with the level of economic development and emissions[9], and with the environmental standards[10]. The least developed countries tend to adopt relatively low(er) environmental standards (Copeland and Taylor, 1994; de Melo and Solleder, 2020), while preferring to target economic growth (de Melo and Solleder, 2020; Pegels and Altenburg, 2020).

The literature on mass produced estimate[11] suggests disentangling the effects of the technical measures across countries and sectors. (e.g., Kee et al., 2009; Bratt, 2017; Ghodsi et al., 2017). The heterogenous effects subtend differences in regulation across sectors, with the industrial (more technologically advanced) sectors are the most affected. Consequently, the less developed countries may have limited market access in developed economies.

2.2. Stylised facts

We describe stylised facts to corroborate the evidence just described in the previous sections (Section 1 and Section 2.1).

Stylised Fact #1: Environmental technical measures are on the rise, by number and relevance.

According to the WTO TBT IMS, from 1995 to 2020 the WTO Members notified 8,902 technical measures under the TBT Agreement, 62 percent of which notified since 2010[12]. Figure 1 sketches the evolution of technical measures by non-trade policy objective overtime. Measures notified for the protection of human health or safety and for quality requirements are dominant: the sensitive nature of issues covered by these measures draws them close to SPS measures. Second by relevance are measures notified for the prevention of deceptive practices and consumer protection and for reducing trade barriers and facilitating trade. The bronze medal goes to measures notified for the protection of the environment, joint with measures of harmonisation.

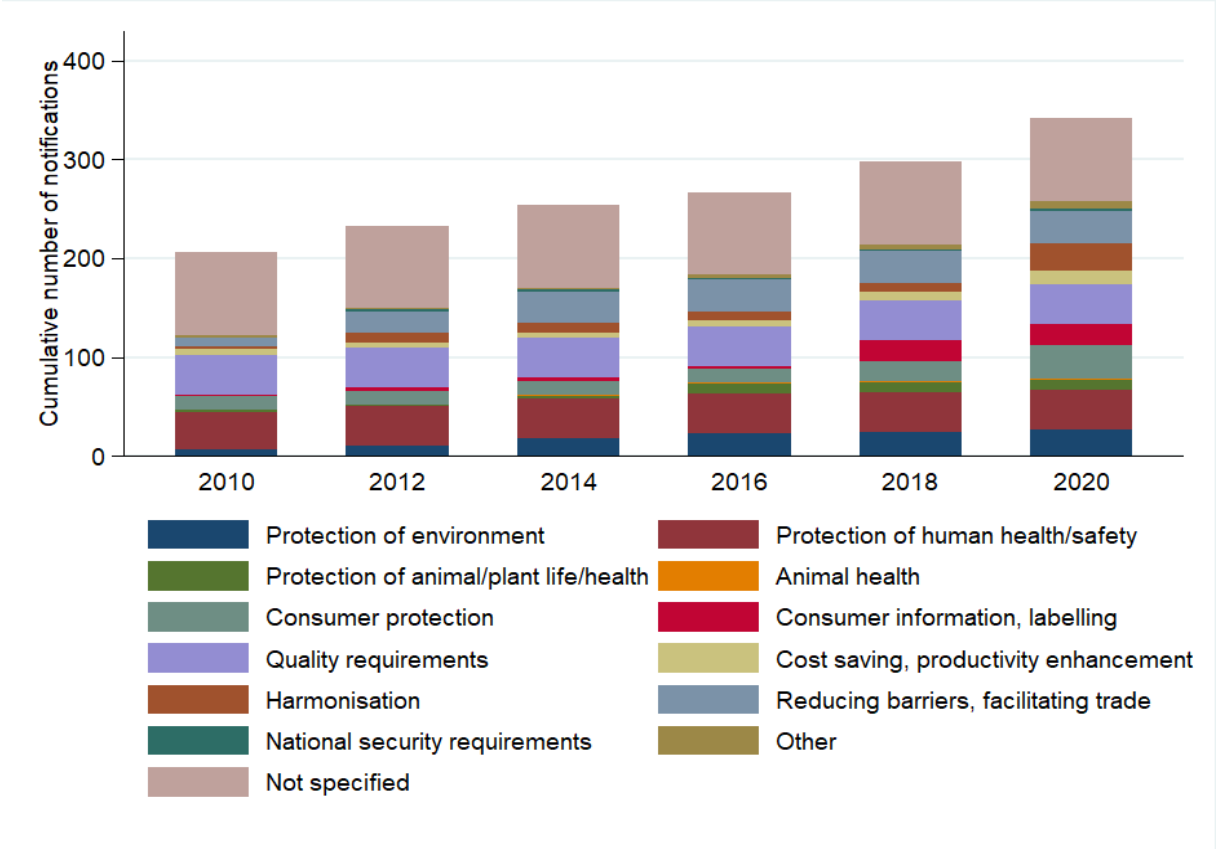
9 Copeland et al. (2022) argue that the pollution emission rates differ substantially across countries, with the vast majority of emissions coming from developing countries.

10 The environmental policies are typically more stringent in high-income countries (de Melo and Solleder, 2020).

11 We are referring here to studies assessing trade on all tariff lines at the 6-digit level of the Harmonised System, also named "mass-produced" estimates, as compared to the "handicraft" estimates which are computed taking into consideration "*one product and country at a time, controlling for time-varying forces that might affect each product and country pair differently*" (Dolabella, 2020, p.16).

12 Figures refer to regular notifications. Notifications of revisions, addenda and corrigenda of existing technical measures are excluded here.

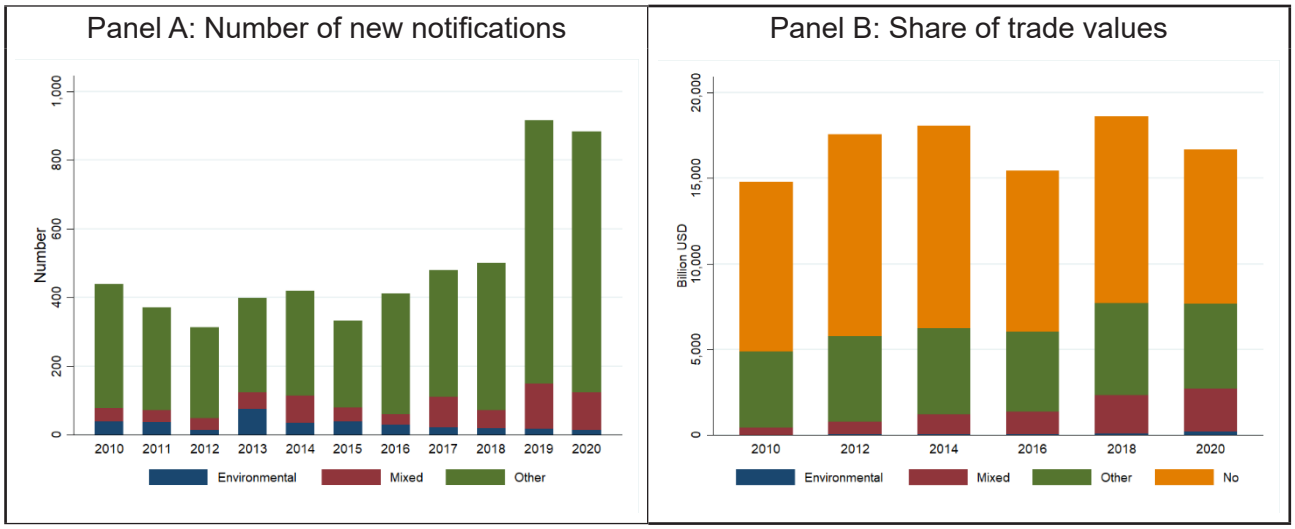
Figure 1. Evolution of technical measures by non-trade policy objective, 2010-2020.



Source: Authors' elaboration on WTO TBT IMS.

The environment-related technical measures moved from 114 notified before 2010 to 1,359 notified in 2010-2020, with a giant increase (about 1,100 percent) and notification peaks in 2013-2014 and in 2019-2020 (figure 2, panel A). The measures notified at the WTO may pursue single (4 percent) or multiple (12 percent) non-trade policy objectives. Therefore, the environmental measures hereafter named '*stricto sensu*' (i.e., single objective) are less frequent than the environmental measures named '*lato sensu*' (i.e., multiple objectives), which target several other objectives, such as the protection of human, animal, and plant health, and are only partially related to the environment. The share of trade regulated by environmental measures is also increasing overtime (figure 2 panel B and figure A.1 in the Appendix A).

Figure 2. Evolution of technical measures and trade overtime, 2010-2020.



Source: Authors' elaboration on WTO TBT IMS and BACI.

Stylised Fact #2: Most of environmental technical measures come from wealthier countries.

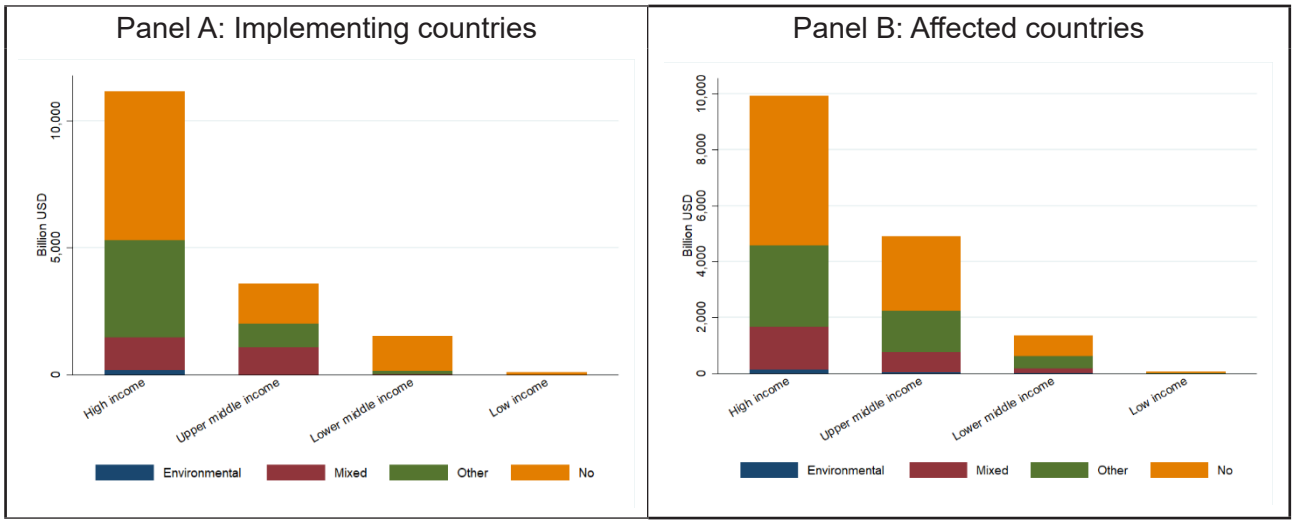
The measures are often justified on the grounds of collective preferences: wealthier countries tend to pay more attention to environmental issues (Fontagné et al., 2005a). Accordingly, the share of trade regulated by environmental measures is larger for the most developed countries (figure 3 and figure A.2 in the Appendix A).

Among the 107 countries notifying technical measures, only 22 notify *stricto sensu*[13] measures, with the United States being on top in terms of number of implemented regulations (129, accounting for 33 percent of total), followed by China (16 percent), Chinese Taipei (8 percent), Thailand (8 percent), and Japan (6 percent). The measures usually refer to product quality, safety or performance requirements (class B7 of TBT, as defined by the Multi-Agency Support Team, MAST group), testing requirements (class B82), and labelling requirements (class B31) (table 1).

The share of regulated imports is therefore larger in wealthier notifying country (figure 3, panel A). Differently, for less developed countries the share of regulated exports is sensibly lower (figure 3, panel B).

13 Countries notifying environmental measures are Australia, Bahrein, Bolivia, Canada, Chile, China, Colombia, Germany, Ecuador, Hong Kong, India, Japan, Korea, Mexico, Pakistan, Peru, Paraguay, Singapore, Turkey, Taiwan, the United States, Zimbabwe.

Figure 3. Trade values regulated by technical measures by groups of countries, 2020.



Source: Authors' elaboration on WTO TBT IMS and BACI.

Table 1. Types of environmental TBT by top implementing countries.

Class of TBT	Description	United States	China	Chinese Taipei	Thailand	Japan
B14	Authorisation requirements for importing certain products	1.5				4.0
B15	Authorisation requirements for importers	4.7		3.1		
B22	Restricted use of certain substances	9.3	1.6	3.1		12.0
B31	Labelling requirements	4.7	1.6	31.2	3.3	8.0
B33	Packaging requirements		1.6			
B41	Technical barriers to trade regulations on production processes	7.8				
B42	Technical barriers to trade regulations on transport and storage		1.6			
B6	Product identity requirements	7.8			73.3	
B7	Product quality, safety or performance requirements	54.3	91.9	87.5	100.0	84.0
B81	Product registration/approval requirements	1.5				
B82	Testing requirements	38.0	61.3	50.0	50.0	4.0
B83	Certification requirements	10.9				4.0
B84	Inspection requirements		1.6	15.6		

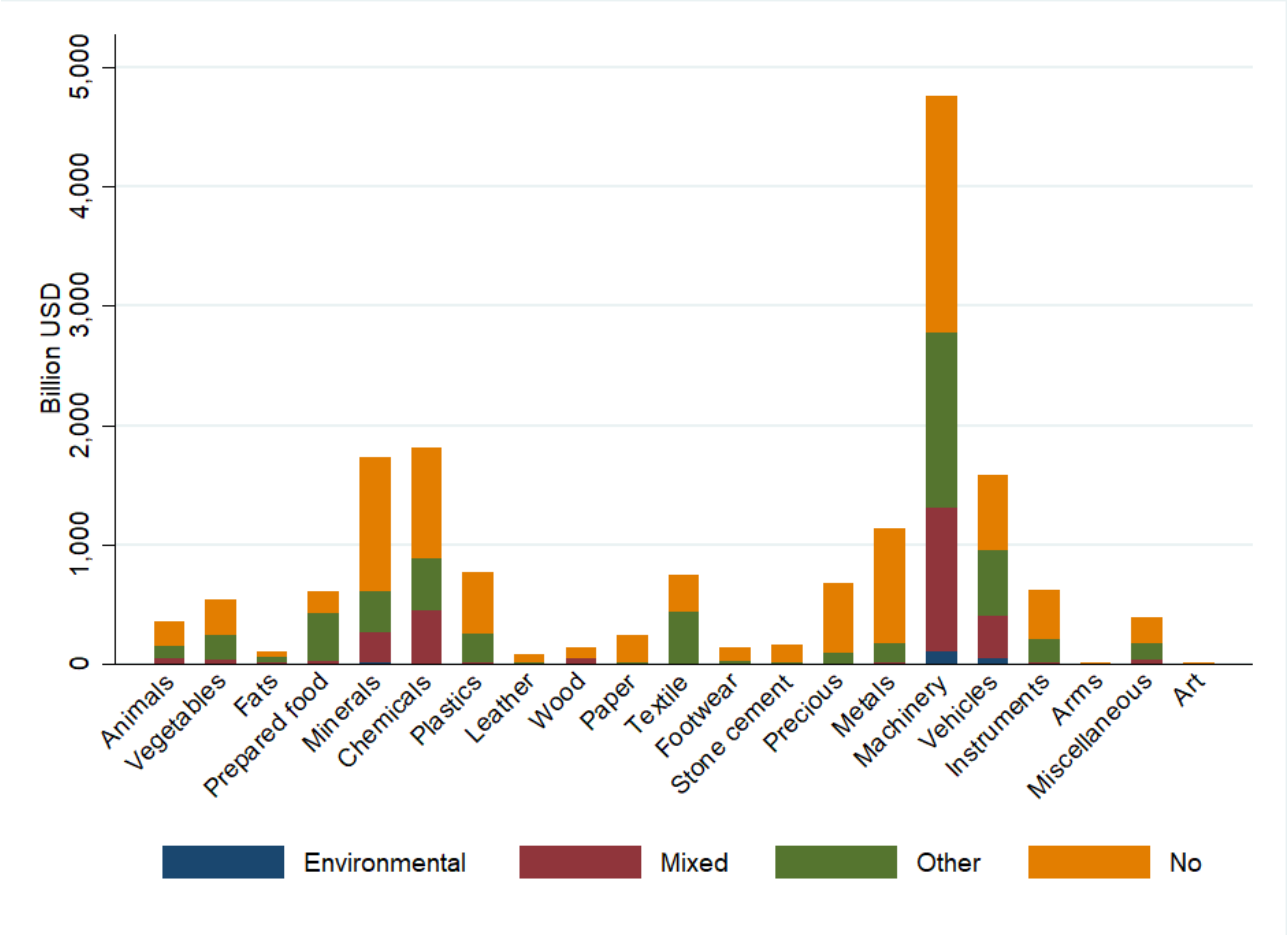
Source: Authors' elaboration on WTO TBT IMS and UNCTAD (2019).

Notes: Figures in the table are percentage with respect to the total environmental measures of each implementing country. The total may be greater than 100 percent since the same environmental measure may fall in more than one class of TBT, defined by the Multi-Agency Support Team (i.e., MAST group).

Stylised Fact #3: Environmental technical measures differ substantially across sectors.

The environmental protection is a greater concern (in absolute terms) for some sectors (e.g., machinery, vehicles, minerals, and chemicals). It is also particularly relevant (in terms of share of trade values) for the agri-food sector (figure 4 and figure A.3 in the Appendix A).

Figure 4. Trade values regulated by technical measures by sector, 2020.



Source: Authors' elaboration on WTO TBT IMS and BACI.

The top three regulated sectors are machinery and mechanical appliances, boilers, nuclear reactors (HS: 84), electrical machinery (HS: 85), and vehicles (HS: 87) which account, respectively, for 42, 20, and 10 percent of total notifications for environmental reasons. More than the half of the measures are related to product quality, safety or performance requirements, thus fall under the class B7 of TBT (table 2). Environmental measures affecting machinery, electrical machinery, and vehicles frequently impose testing (class B82) and certification (class B83) requirements as well as a restricted use of certain substances (class B22).

Table 2. Types of environmental TBT by top affected sectors.

Class of TBT	Description	Machinery (HS:84)	Electrical machinery (HS:85)	Vehicles (HS: 87)
B15	Authorisation requirements for importers	0.6	3.3	1.4
B22	Restricted use of certain substances	7.5	2.6	12.5
B31	Labelling requirements	1.6		5.6
B32	Marking requirements	0.3		
B41	Technical barriers to trade regulations on production processes		1.3	2.8
B6	Product identity requirements	6.2	7.8	
B7	Product quality, safety or performance requirements	55.3	59.5	61.1
B8	Conformity assessment related to technical barriers to trade		0.7	
B81	Product registration/ approval requirements			1.4
B82	Testing requirements	24.7	30.7	16.7
B83	Certification requirements	7.2	2.6	1.4
B84	Inspection requirements	2.2	0.7	

Source: Authors' elaboration on WTO TBT IMS and UNCTAD (2019).

Notes: Figures in the table are percentage with respect to the total environmental measures of each sector. The total may be greater than 100 percent since the same environmental measure may fall in more than one class of TBT, defined by the Multi-Agency Support Team (i.e., MAST group).

A unique dataset of notifications

We create a unique and original dataset of technical measures notified under the WTO TBT Agreement, gathering information on regular notifications from the WTO TBT IMS. We do not consider revisions, addenda and corrigenda of existing technical measures[14], except their removal.

The WTO Members (i.e., implementing countries) may unilaterally[15] notify technical measures on specific products (at the 6-digit level of the Harmonised System, HS), or categories (at the HS4-digit level), or sectors (at the HS2-digit level). We convert the information on notifications into combinations of implementing country and HS6-digit product[16] to favour the correspondence with trade data[17]. Data on bilateral trade originates from the BACI, a detailed international trade database released by the CEPII. The original database covers two hundreds countries and five thousands products, until 2020. Our dataset includes trade values (in current USD) and volumes (in tons) for 4,958 products at the HS6-digit level, covering all the 96 HS2-digit sectors, and 156 potential trading partners. The variables are described in table 3: the value of trade originating in high-income countries is about three times higher than those of low-income countries[18], despite the larger trade volumes originating in low income countries. Similar considerations apply to the comparison between countries characterised by high and low environmental quality[19]. Trade from more industrialised countries shows a growth between 2010 and 2020, mostly due to a price effect (i.e., from 353 to 576 thousand USD per ton for G20 countries and from 308 to 690 thousand USD per ton for big emitters[20]).

14 Reasons for addenda or corrigenda may be the following: comment period changed; notified measure adopted; notified measure published; notified measure enters into force; text of final measure available from; notified measure withdrawn or revoked; content or scope of notified measure changed; interpretative guidance issued and text available from; clerical error in notification; clerical error in notified measure.

15 Notified measures apply indiscriminately to all trading partners of the notifying country.

16 If measures affect categories at the HS4-digit level or sectors at the HS2-digit level, they are attributed to all traded HS6-digit products within the HS4-digit category or HS2-digit sector.

17 Technical measures are reported on a daily basis in the WTO TBT IMS. To build an annual dataset, we assume that measures are implemented in a given year if the date of notification is in the first half of the year, and the other year otherwise. For instance, the United States notified two technical measures related to the Regulation of Fuels and Fuel Additives: one on 20 January 2012, the other on 3 October 2012. The official WTO documents of the notifications are available at: https://docs.wto.org/imrd/directdoc.asp?DDFDocuments/t/G/Tbtn12/USA674.DOC and https://docs.wto.org/imrd/directdoc.asp?DDFDocuments/t/G/Tbtn12/USA754.DOC (accessed on March 06, 2023). We assume that the measure notified on January is implemented in 2012 and the measure notified on October is implemented in 2013. By doing so, we consider the period between the notification of a measure and its entry into force that, on average, ranges between three and nine months. This delay between the notification and entry into force periods is in line with article 2.9.4 and 5.6.4 of the WTO TBT Agreements, according to which "*Members shall without discrimination, allow reasonable time for other Members to make comments in writing, discuss these comments upon request, and take these written comments and the results of these discussions into account*".

18 Countries are grouped into high or low income countries according to the World Development Indicators of the World Bank.

19 The 2020 Environmental Performance Index (EPI) of the Yale University allows us to distinguish between countries with low (values of EPI lower than 33) and high (values of EPI higher than 66) environmental quality.

20 Big emitters are countries with total greenhouse gas emissions higher than 5,000 Mt CO_2eq, according to Climate Watch.

Table 3. Descriptive statistics of main variables, by groups of countries facing technical measures.

	All		High income		Low income		G20		Big emitters		High env-quality		Low env-quality	
Variable	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020
Values	1.7	1.7	1.7	1.7	0.5	0.7	1.9	1.9	3.2	1.7	1.7	1.8	1.2	1.1
(mln USD)	(±59.8)	(±62.0)	(±56.6)	(±56.6)	(±26.7)	(±33.6)	(±60.6)	(±65.9)	(±71.0)	(±62.0)	(±51.6)	(±57.9)	(±73.0)	(±34.0)
Volumes	1.4	1.4	1.1	1.2	0.9	1.6	1.4	1.5	1.8	1.4	1.0	1.2	1.5	1.8
('000 tons)	(±284.0)	(±272.3)	(±166.6)	(±312.3)	(±46.3)	(±187.6)	(±330.3)	(±314.3)	(±651.8)	(±272.3)	(±170.6)	(±339.3)	(±231.0)	(±166.2)
Unit values	0.5	0.7	0.5	0.8	0.2	0.4	0.4	0.6	0.3	0.7	0.6	0.8	0.3	0.9
(mln USD/tons)	(±81.9)	(±164.0)	(±99.3)	(±198.2)	(±8.2)	(±28.5)	(±47.7)	(±104.5)	(±69.1)	(±164.0)	(±103.7)	(±200.0)	(±18.4)	(±113.2)
Env-TBT	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(nbr)	[1; 1]	[1; 5]	[1; 1]	[1; 5]	[1; 1]	[1; 3]	[1; 1]	[1; 5]	[1; 1]	[1; 5]	[1; 1]	[1; 5]	[1; 1]	[1; 5]
Obs. with env-TBT	0.01	0.4	0.01	0.4	0.004	0.8	0.01	0.4	0.004	0.4	0.01	0.4	0.01	0.5
(%)	(±0.8)	(±6.5)	(±0.8)	(±6.4)	(±0.7)	(±9.1)	(±0.7)	(±6.2)	(±0.6)	(±6.5)	(±0.8)	(±6.3)	(±0.8)	(±6.7)
Mix-TBT	2	3	2	3	2	4	2	3	2	3	2	3	2	3
(nbr)	[1; 93]	[1; 114]	[1; 93]	[1; 114]	[1; 91]	[1; 112]	[1; 93]	[1; 114]	[1; 93]	[1; 114]	[1; 93]	[1; 114]	[1; 93]	[1; 114]
Obs. with mix-TBT	19.2	25.5	20.1	26.4	16.4	25.6	19.4	25.5	14.9	25.5	19.9	26.2	16.8	23.2
(%)	(±39.4)	(±43.6)	(±40.1)	(±44.1)	(±37.1)	(±43.6)	(±39.5)	(±43.6)	(±35.6)	(±43.6)	(±39.9)	(±44.0)	(±37.4)	(±42.2)
Oth-TBT	2	2	2	2	2	3	2	2	2	2	2	2	2	2
(nbr)	[1; 87]	[1; 94]	[1; 87]	[1; 94]	[1; 87]	[1; 94]	[1; 87]	[1; 94]	[1; 87]	[1; 94]	[1; 87]	[1; 94]	[1; 87]	[1; 94]
Obs. with oth-TBT	18.8	21.0	19.7	21.4	16.0	22.8	19.0	20.7	14.7	21.0	19.5	21.1	16.4	19.5
(%)	(±39.1)	(±40.7)	(±39.8)	(±41.0)	(±36.7)	(±42.0)	(±39.2)	(±40.5)	(±35.4)	(±40.7)	(±39.6)	(±40.8)	(±37.1)	(±39.6)

Notes: Descriptive statistics are average, standard deviation in parentheses, minimum and maximum in brackets.

The WTO TBT IMS notifications of technical measures are classified into thirteen non-trade policy objectives: (1) protection of the environment, (2) protection of human health or safety, (3) protection of animal or plant life or health, (4) animal health, (5) prevention of deceptive practices and consumer protection, (6) consumer information, labelling, (7) quality requirements, (8) cost saving and productivity enhancement, (9) harmonisation, (10) reducing trade barriers and facilitating trade, (11) national security requirements, (12) other (i.e., other than the list of objectives), (13) not specified (i.e., notification not associated to any specific objective). For each combination of implementing country, HS6-digit product, and non-trade policy objective, the variable related to the notifications include the stock of technical measures notified since 1995 (i.e., the starting date of the WTO TBT IMS).

We group notifications into three categories: environmental (accounting for 0.01 percent in 2010, and 0.4 percent in 2020), mixed (from 19.2 to 25.5 percent, on average, between 2010 and 2020), and other TBT (moving from 18.8 to 21.0 percent) (table 3). The environmental TBT includes notifications which are solely related to environmental objectives: this category is the focus of our analysis (i.e., environmental measures *stricto sensu*). Technical measures with environmental purposes started to be notified after the second decade of the century. For this reason, we build a panel of six years (every other year, starting in 2010) of bilateral trade flows and technical measures: the dataset includes more than fifty-six millions of observations in total.

The category of mixed TBT collects measures notified for environmental and other objectives. The last category includes measures notified for objectives other than the protection of the environment. The mixed TBT and the other TBT address non-trade policy objectives of different nature, such as market-related objectives (e.g., cost saving and productivity enhancement, reducing trade barriers and facilitating trade), consumer-related objectives (e.g., prevention of deceptive practices and consumer protection, consumer information, labelling), safety-related objectives (e.g., protection of human health or safety, protection of animal or plant life or health). These measures are control factors, and the benchmark for our estimates.

The environmental TBT and the mixed TBT are quite different. For instance, the United States and China regulated fertilisers, respectively in 2013 and in 2019[21]. The measure notified by China, dealing with toxic and harmful elements in fertilisers, relates to the protection of the environment as well as to the protection of animal and plant health. Differently, the measure notified by the United States addresses only environmental issues, establishing conditions under which a fertilising material is considered an organic input material (requiring labelling and registration); it mandates a laboratory analysis to be included with a product label during registration under specified circumstances, it also clarifies sampling and recordkeeping requirements. Undoubtedly, the content of the two measures is quite different, (table 4).

21 The official WTO documents of the notifications are available at: https://docs.wto.org/imrd/directdoc.asp?DDFDocuments/t/G/Tbtn13/USA804.DOC and https://docs.wto.org/imrd/directdoc.asp?DDFDocuments/t/G/TBTN19/CHN1349.DOCX (accessed on March 06, 2023).

Table 4. Example of environmental TBT.

Country-sector-year	Description	Content
	Conditions when a fertilising material is considered an organic input material requiring labelling and registration	The concentration limits are: arsenic 104 parts per million, cadmium 208 parts per million, lead 1,040 parts per million for a guaranteed available 52 percent phosphate product, arsenic 36 parts per million, cadmium 44 parts per million, lead 380 parts per million for a guaranteed available 3 percent phosphate product with 2 percent guaranteed zinc.
United States, fertilisers, 2013	Laboratory analysis to be included with a product label during registration under specified circumstances	The label of each product which contains organisms, enzymes, and other biologically active by-products of organisms for which claims are made shall state: name of each species and strains as part of the statement of composition and name of each by-product, if claimed, percentage or number of viable units of microorganisms per cubic centimetres or per gram for dry material, concentration in percentage of enzymes or other organism by-products claimed, expiration date for use, storage conditions. A copy of the analysis, must be submitted with the registration application.
	Sampling and recordkeeping requirements	Authorised staff may take a sample for analysis from any lot of fertilising material which is in the possession of any producer, manufacturer, importer, agent, dealer, or user. Each licensee shall maintain an accurate record of all transactions subject to assessment for a period of not less than three years following the transaction.

Source: WTO TBT IMS. The official WTO documents of the notification are available at: https://docs.wto.org/imrd/directdoc.asp?DDFDocuments/t/G/Tbtn13/USA804.DOC (accessed on March 06, 2023).

3. Empirical framework

The empirical framework is admittedly simple: we model bilateral trade between *i* (exporter) and *j* (importer), for each product *k*, in year *t*. The specification is based on the gravity model (e.g., Costinot and Rodriguez-Clare, 2014; Head and Mayer, 2014) and, more precisely, we use a quantity-impact method, widely adopted in the economic literature on the trade effects of the NTMs (e.g., Disdier et al., 2008; Orefice, 2017; Ghodsi and Stehrer, 2022):

$$\boldsymbol{Y}_{ijkt} = \alpha_{ikt} + \alpha_{jt} + \alpha_{ij} + \beta_z \boldsymbol{TBT}^{z}_{jkt} + \gamma AVE_{ijkt} + \delta RTA_{ijt} + \varepsilon_{ijkt} \quad (1)$$

Because technical measure may affect differently the volume and the values of trade, though price effects (UNCTAD, 2010; UNCTAD, 2019), our dependent variable $\boldsymbol{Y}_{jkt}$ is, alternatively, the annual level of product-specific bilateral values (i.e., v_{jkt}), volumes (i.e., q_{jkt}), and unit values (i.e., uv_{jkt}) being traded.

Technical measures are modelled as dummies, equal to one if the importer *j* notifies at least one technical measure of type ***z*** on product *k* in year *t* (i.e., $\boldsymbol{TBT}_{jkt}^{z}$)[22]. The dummy controls for the presence of a specific type of technical measures, and the estimated β_z inform on the effect of having at least one technical measure of type ***z*** in place (e.g., Crivelli and Gröschl, 2016; Santeramo and Lamonaca, 2022). We distinguish the three types of technical measures. The vector *z* includes measures notified solely for an environmental objective (i.e., TBT_{jkt}^{env}), measures addressing mixed (both environmental and non-environmental) objectives (i.e., TBT_{jkt}^{mixed}), and measures related to objectives other than the environmental protection (i.e., TBT_{jkt}^{other}). To isolate the effects of measures notified for the protection of the environment we refer to the mixed and other technical measures as control factors.

We use a three-way fixed effects specification (e.g., Weidner and Zylkin, 2021). Time-varying exporter-product fixed effects (i.e., a_{ikt}) are supply-side controls tracking, over time, the product-specific production capacity of the exporting country. They also absorb the time-varying product-specific value of production of the exporter. Time-varying importer fixed effects[23] (i.e., a_{jt}) control for the importing country demand-specific characteristics, such as total expenditure. The exporter-product-time and importer-time fixed effects also allow us to capture the outward (exporter) and inward (importer) multilateral resistances (Anderson and Van Wincoop, 2003). Bilateral fixed effects (i.e., a_{ij}) account for any unobservable time-invariant bilateral component (Egger and Nigai, 2015), such as the geographic distance or the cultural proximity across trading partners.

Wooldridge (2010) argues that the panel data fixed effects estimation allows to estimate the effects of time-varying independent variables (i.e., technical measures in our specification) in the presence of time-constant omitted variables (i.e., bilateral controls in our specification). Although fixed effects estimation eliminates time-constant explanatory variables, this technique does not solve the problem of time-varying omitted variables that are correlated with the explanatory variables. This concern justifies the introduction of time-varying control variables in the gravity equation. As suggested by Yotov et al. (2016), we introduce the annual *ad valorem* equivalent of the tariff applied by the importer *j* to the product *k* coming from the exporter *i* (i.e., AVE_{ijkt}), and a binary variable indicating whether the trading partners *i* and *j* share at least a trade agreement the year *t* (i.e., RTA_{ijkt}). Tariff data stems from Market Access Map (MAcMap) by CEPII, which provides an *ad valorem equivalent* (percentage) of applied tariff duties for each importer-exporter-HS6-digit product across years, exhaustively

22 Although technical measures are notified on a multilateral basis (i.e., the measure notified applies to domestic market and to any potential trading partners of the notifying country), they affect each single bilateral relationship.

23 Our baseline approach consists in excluding the product dimension *k* from demand-side fixed effects. This specification controls for the average competitiveness of importing countries and left unexplored the sector specific component of the inward multilateral resistance. As robustness check, we apply the two-step fixed effects estimator proposed by Honoré and Kesina (2017) to account for the time-varying sector specific competitiveness of importing countries. Additional methodological details are provided in the Appendix B.

considering regional agreements and trade preferences. Information on regional trade agreements is form the WTO.

Following Wooldridge (2010) we address potential endogeneity issues due to omitted variables, simultaneity and measurement errors, using an instrumental variable (IV) approach.

We run ordinary least squares (OLS)[24] over the period 2010-2020, with two-years intervals (i.e., 2010, 2012, 2014, 2016, 2018, 2020) to allow for slow adjustments of trade to policy (e.g., Trefler, 2004; Cheng and Wall, 2005; Baier and Bergstrand, 2007; Olivero and Yotov, 2012). The random error term are clustered at the country-pair-product level, so as to account for heteroskedasticity and serial correlation that may occur with large panel dimension and small time dimension (Wooldridge, 2002; Wooldridge, 2010).

We convert the estimates into trade volume effects (TVE), by applying the formula synthesised in Yotov et al. (2016). The TVEs, expressed in percentage terms, are computed as follows:
$TVE^z = (e^{\widehat{\beta^z}} - 1)$ * 100, where $\widehat{\beta^z}$ is the estimate of the effects of a technical measure of type *z*.

4. Empirical evidence

4.1. Effect of environmental measures on trade outcomes

We compare the effects of environmental measures on trade outcomes, specifically on trade values (model A), volumes (model B), and unit values (model C). Table 5 shows the estimated effects of technical measures addressing environmental issues (i.e., TBT_{jkt}^{env}) and omits, for brevity, the coefficients estimated for control variables[25]. We compare results for flows above 10,000 USD (table 5, columns 1.a, 1.b, and 1.c), a threshold conventionally used in trade literature[26] (e.g., Ghodsi and Stehrer, 2022), as well as for all flows[27] (table 5, columns 2.a, 2.b, and 2.c). In these specifications, we rely on the intensive margin of trade and zero trade flows are not included. However, a robustness check on the extensive margin of trade is presented in table D.3 of the Appendix D and confirms our findings.

24 The OLS estimator requires the natural logarithm of dependent variables (i.e., *ln* v_{ijkt}, *ln* q_{ijkt}, and *ln* uv_{ijkt}) and of continuous explanatory variables (i.e., AVE_{ijkt}). Gravity-based analyses frequently rely on a Poisson Pseudo Maximum Likelihood (PPML) estimator (Santos Silva and Tenreyro, 2006), which allows to handle the presence of zero trade flows. However, this issue is out of the scope of our empirical application based on the intensive margin of trade. We run a PPML estimation as robustness check on the baseline model, both on the extensive and intensive margin of trade.

25 Other technical measures (i.e., notified not only for environmental reasons –mixed TBT– and with objectives other than the protection of the environment –other TBT–), *ad valorem* tariffs, and the presence of trade agreements between partners are controls. Since the coefficients estimated for control variables are not the focus of our analysis, they are omitted in the following tables but reported in the Appendix D for transparency.

26 Some studies do not consider observations for products that never exceed an arbitrary threshold of trade value (i.e., 10,000 USD) during the analysed periods (e.g., Ghodsi and Stehrer, 2022). This methodological choice is justified by the fact that national customs do not have the same reporting threshold (Gaulier et al., 2008; Gaulier and Zignago, 2008). The reporting thresholds are neither equal across countries, nor constant over time. For instance, the EU legislation fixes the maximum level of the individual transaction threshold at EUR 200 (Eurostat, 2016; more information available here: https://unstats.un.org/wiki/pages/viewpage.action?pageId=6325285, accessed on March 08, 2023). The Trade Statistics and Customs Analysis team of the United Kingdom does not receive business, product or partner country information on movements that fall under the statistical value threshold of 873 GBP (more information available here: https://www.gov.uk/government/statistics/overseas-trade-statistics-methodologies/regional-trade-in-goods-statistics-methodology, accessed on March 08, 2023). The US Census Bureau fully compiled import statistics on shipments valued over $2,000 (or $250 for certain quota items) for any article required to be reported on a formal entry (more information available here: https://www.census.gov/foreign-trade/guide/sec2.html, accessed on March 08, 2023).

27 Small trade flows represent 47% of observations in our sample. While small flows are considered economically not relevant in macro-level analyses, they may be crucial in the understanding of the effects of policies negotiated at the product level, such as technical measures, and affecting bilateral relationships. A sensitivity analysis on small flows is presented in table D.1 of the Appendix D.

The effect of environmental measures tends to be positive and driven by a price increase (table 5, columns 1.a and 1.c). The IV coefficient, omitted for brevity and reported in table C.1 of the Appendix C, is about four times larger. Coherently with previous studies, not controlling for endogeneity underestimates the trade effects of non-tariff measures (e.g., Trefler, 1993; Lee and Swagel, 1997; Essaji, 2008; Kee et al., 2008): the trade effects of environmental measures listed in table 5 represent lower bound estimates. The trade volume effects are synthesised in table 6.

Table 5. Effect of environmental technical measures on trade outcomes.

	(A) Values		(B) Volumes		(C) Unit values	
Dependent variable	ln v_{ijkt}		ln q_{ijkt}		ln uv_{ijkt}	
	(1.a)	(2.a)	(1.b)	(2.b)	(1.c)	(2.c)
Variable [coefficient]	Flows > 10,000 USD	Flows (small flows included)	Flows > 10,000 USD	Flows (small flows included)	Flows > 10,000 USD	Flows (small flows included)
TBT_{jkt}^{env} $[\hat{B}^{env}]$	0.0236**	-0.0092	0.0081	0.0244*	0.0214***	-0.0116*
	(0.0112)	(0.0118)	(0.0139)	(0.0137)	(0.0075)	(0.0066)
Observations	29,579,034	55,824,664	29,323,161	54,443,084	29,323,161	54,443,084

Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade values (ln v_{jkt}) in columns (1.a) and (2.a), volumes (ln q_{jkt}) in columns (1.b) and (2.b), and unit values (ln uv_{jkt}) in columns (1.c) and (2.c). All specifications include dummy variables proxying the presence of at least one environmental TBT (TBT_{jkt}^{env}), one mixed TBT (i.e., notified for both environmental and other non-trade policy objectives), one other TBT (i.e., notified for non-trade policy objectives other than the environmental protection), (the natural logarithm of the) *ad valorem* equivalent of tariff (*AVE*), a dummy variable indicating the presence of trade agreements between partners, and fixed effects (i.e., a_{ikt}, a_{kt}, a_{ij}). Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), product at the 6-digit of the Harmonised System (*k*), year (*t*). For each model (columns A, B, and C), specifications (2) include bilateral trade flows lower than 10,000 USD. The number of observations in models (B) and (C) lower than in model (A) is due to the presence of missing in the variable q_{jkt}. Zero trade flows are excluded. Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 6. Trade volume effects of environmental technical measures on trade outcomes.

Flows	Values	Volumes	Unit values
Flows > 10,000 USD	+2.4	0	+2.2
Flows (small flows included)	0	+2.5	-1.2

Notes: Trade volume effects are in percentage.

The average trade effects on values (i.e., the estimates from the whole sample) are null, with differentiated impacts on quantities and unit prices: the technical regulations increase the traded quantities (by 2.5 percent) and reduce (by 1.2 percent) unit values. Coherently with extant literature on NTMs, the trade-impeding and trade-enhancing effects of technical measures may coexist and offset each other at the aggregate level (e.g., Li and Beghin, 2012; Santeramo and Lamonaca, 2019; Adarov and Ghodsi, 2023). Enforcing a behind-the-border measures ensures the coexistence of arguments in favour of a positive impact, based on informational considerations, and a negative impact, driven by hidden green protectionism (Fontagné et al., 2005b).

Environmental measures tend to boost (by 2.4 percent) flows exceeding the threshold of 10,000 USD, due to a positive effect (by 2.2 percent) on unit prices or goods regulated by environment related TBTs. For instance, the trade between Australia and Thailand that was not subject to environmental measures accounted for 4 million USD in 2020, with average unit values of 0.5 million USD per ton (i.e., half dollar per bushel). If Australia were notifying at least one environmental measure, the value of trade would have expanded by 96 thousand USD, due to an average increase (by a cent) in unit prices of all traded goods.

The compliance with technical measures imposes high costs associated, for instance, with the use of costly inputs or the implementation of recurrent control and product testing (e.g., Fontagné et al., 2015). These additional costs, faced by producers, increase the cost of the final products, thus their trade unit values (Adarov and Ghodsi, 2023). The increase in the trade unit values induced by technical measures may be due to the higher quality of goods traded under environmental standards (e.g., Feenstra and Romalis, 2014; Gaigné et al., 2021). This is consistent with the Alchian–Allen conjecture, originally proposed by Alchian and Allen (1964) and formalised by Hummels and Skiba (2004), which states that the relative demand for high-quality goods increases in the per unit freight rate. Recent empirical evidence demonstrates that per-unit trade costs induce higher trade unit values (Emlinger and Guimbard, 2021). Driven by a price effect, the value of trade may expand when the implementation of technical measures, by addressing market failures such as externalities or information asymmetries, enforces the perceived quality of imported goods (Beghin et al., 2015).

4.2. Driving mechanisms of trade effects

4.2.1. Timing and placement of a growing number of notifications

The effect of technical measures on bilateral trade flows may suffer from reverse causality, which occurs when trade measures are implemented to regulate larger trade flows. The reverse causality between measures and trade may come from biased policy placement: for example, technical measures may be notified where they are most needed, that is where there are relevant trade flows that need to be regulated (e.g., Trefler, 1993; Kee et al., 2008). In this case technical measures are positively correlated with (and appear to be the cause of) bilateral trade flows, but the correlation cannot imply causation.

To test for possible reverse causality, we adopt the strict exogeneity assumptions on the explanatory variables, discussed in Wooldridge (2010). In the baseline specification, we add a variable capturing the future level of technical measures (i.e., $\boldsymbol{TBT}_{jkt+1}^{z}$), whose estimated coefficients should be statistically not different from zero to exclude reverse causality between measures and trade flows. Then, we include lagged environmental measures (i.e., $\boldsymbol{TBT}_{jkt-1}^{z}$ and $\boldsymbol{TBT}_{jkt-2}^{z}$), as suggested, for example, in Baier and Bergstrand (2007) and Anderson and Yotov (2016). Table 7 compares the baseline effects of environmental measures (with current levels of measures only, columns 1.a and 1.b) to effects estimated controlling for potential reverse causality, with the addition of future levels of measures (columns 2.a and 2.b) and both future and past levels of measures (columns 3.a and 3.b).

As robustness check, the baseline specification (column 1.b) is estimated on a sample that excludes the year 2020 so as to mimic the reduction of the sample due to the introduction of the forwarded variables (column 2.b), and on a sample that excludes the years 2010, 2012, and 2020 to simulate the reduction of the sample due to the introduction of the lagged and forwarded variables (column 3.b). The results, omitted for brevity, are consistent with the estimates shown in table 7.

We use of alternative proxies for multilateral resistances, such as exporter-product-year and importer-year fixed effects as proxies of multilateral resistances (table 7, columns 2.b and 3.b), and adopt a two-step fixed effects estimator (Honoré and Kesina, 2017) to control for exporter-product-year and importer-product-year fixed effects as proxies of multilateral resistances (table B.1 in the Appendix B). The results from both specifications are comparable.

As further check, we estimate the effects of environmental measures with a PPML estimator, to account for potential heteroskedasticity in trade data and for the presence of zero trade flows (see table D.3 of the Appendix D).

Table 7. Timing of environmental technical measures.

	(A) Flows > 10,000 USD			(B) Flows (small flows included)		
Dependent variable	ln v_{jkt}			ln v_{jkt}		
	(1.a)	(2.a)	(3.a)	(1.b)	(2.b)	(3.b)
Variable [coefficient]	Current TBT	Current and future TBT	Current, future, past TBT	Current TBT	Current and future TBT	Current, future, past TBT
TBT_{jkt}^{env} $[\hat{B}^{env}]$	0.0236**	-0.1024***	-0.0853***	-0.0092	-0.0760***	-0.1593***
	(0.0112)	(0.0159)	(0.0203)	(0.0118)	(0.0185)	(0.0242)
TBT_{jkt+1}^{env} $[\hat{B}^{env}]$		0.0603***	0.1039***		-0.0183	0.0953***
		(0.0103)	(0.0118)		(0.0118)	(0.0137)
TBT_{jkt-1}^{env} $[\hat{B}^{env}]$			0.0094			0.0709***
			(0.0204)			(0.0250)
TBT_{jkt-2}^{env} $[\hat{B}^{env}]$			-0.0862***			-0.0630**
			(0.0232)			(0.0284)
Observations	29,579,034	22,795,966	12,106,207	55,824,664	38,922,351	18,082,840

Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade values. All specifications include dummy variables proxying the presence of at least one environmental TBT (TBT_{jkt}^{env}), one mixed TBT (i.e., notified for both environmental and other non-trade policy objectives), one other TBT (i.e., notified for non-trade policy objectives other than the environmental protection), (the natural logarithm of the) *ad valorem* equivalent of tariff (*AVE*), a dummy variable indicating the presence of trade agreements between partners, and fixed effects (i.e., a_{ikt}, a_{jt}, a_{ij}). Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), product at the 6-digit of the Harmonised System (*k*), year (*t*). Model (B) includes also bilateral trade flows lower than 10,000 USD. Zero trade flows are excluded. Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

We reject the hypothesis that environmental measures are strictly exogenous to trade flow changes. The estimated coefficient for the forwarded variable proxying environmental measures is statistically significant in all but one specification, implying a potential correlation between the future notification of environmental measures and the concurrent levels of trade flows. The feedback effects from trade flows to notification of new environmental measures persist after the introduction of the lagged effects of environmental measures on trade.

Two key evidences emerge from this analysis. First, environmental measures are not exogenous to changes in trade flows. Second, and more interestingly, the barrier effect of environmental measures prevails when reverse causality is accounted for in the analysis. The positive effect estimated for trade values above the threshold (see table 2, column 1.a) is likely to be associated with the fact that more environmental measures are notified where there are large trade flows that need to be regulated.

The positive coefficients estimated for the future level of environmental measures (table 7) suggest that the bilateral trade may increase in anticipation of a technical measure notified for the protection of the environment, especially because the notification date does not match with the implementation date (de Melo and Nicita, 2018b) insofar technical measures shall be notified to other countries, to allow reasonable time for comments and to introduce amendments (article 2.9 of the WTO TBT Agreement). This mismatch may induce countries to sale stockpiles of products not complying with the newly proposed measure, creating a temporary increase in trade flows in anticipation of an impending technical measure. Also, feedback effects from changes in trade to changes in environmental measures may signal the propensity of governments to regulate sectors that are strategic for domestic producers and consumers, through the notification of environmental measures in markets characterised by large trade flows (de Melo and Nicita, 2018b).

The statistically significant lagged effects of environmental measures on trade flows suggest that the economic effect of environmental measures is not fully captured in the year of notification. For instance, on July 9, 2012, Japan notified to the WTO the revision of the standard energy consumption, set by the Act on the Rational Use of Energy, of the residential heat pump water heaters using carbon dioxide as refrigerant (i.e., sector HS: 84.18). The rationalisation of overall energy consumption in Japan through popularisation of machineries and equipment with high energy consumption efficiency, promoted by this environmental measure, had the ultimate objective of contributing to cope with the increase of energy consumption in commercial and residential sector, under the global warming problem. While the measure was notified in summer 2012, it was adopted about one year later (in spring 2013) and entered into force in 2017 (i.e., the target fiscal year for meeting the standard)[28]. The results reveal that the cumulative effect (with two lags) of environmental measures on trade flows above the threshold is -0.0676 (table 7, column 3.a), informing that, after a four-year period, the notification of an environmental measure reduces the level of bilateral trade by 6.5 percent.

28 The official WTO document of the notification is available at: https://docs.wto.org/imrd/directdoc.asp?DDFDocuments/q/G/Tbtn12/JPN401.pdf (accessed on February 15, 2023).

4.2.2. Country-specific heterogeneity

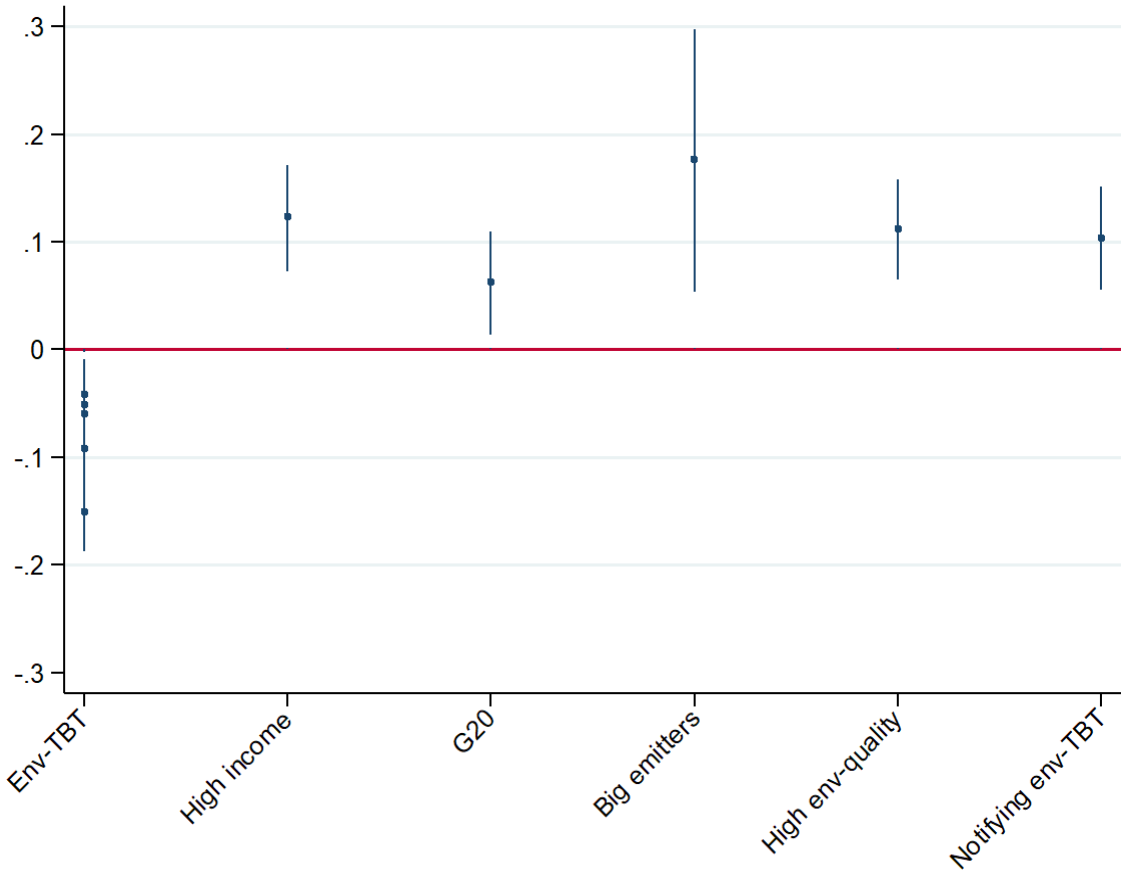
The self-selection of trading partners may contribute to explain the effects of technical measures: the volumes of exports from markets facing technical measures tend to dominate those from countries that are not facing regulations (e.g., Marette and Beghin, 2007; Beghin et al., 2012). Countries (and related firms) with favourable assets may achieve better trade outcomes by accessing markets covered by technical measures (e.g., Bratt, 2017). These assets and trade relationships are likely correlated with macroeconomic characteristics and geopolitical connections (e.g., Bao and Qiu, 2012). A naïve comparison of trade outcomes across countries affected and non-affected by a (environment related) technical measure would not disentangle the effects of the latter from those due to (omitted) country-specific features.

As discussed by Essaji (2008), for the technical measures to be exogenous to the trade mix, a country's ability to comply with technical measures should not be influenced by its specific characteristics. However, this assumption is debatable, as a country's specific characteristics influence its ability to comply with environmental measures (e.g., Fontagné and Orefice, 2018).

To explore the cross-country effect of environmental measures, we interact the environmental measures with country-specific dummies (figure 6, and table D.4 of Appendix D). We estimate the effects for high income countries (label 'High income' in figure 5), as defined by the World Development Indicators of the World Bank to (the baseline estimates, labelled 'env-TBT', refer to the upper middle and lower middle income exporters). We have also grouped G20 countries (label 'G20' in figure 5) to estimate heterogeneous effects across like-minded trading partners (e.g., Bao and Qiu, 2012).

The level of economic development correlates with emissions level and environmental standards (e.g., de Melo and Solleder, 2020): we estimate the trade effects for big (labelled as 'big emitters' in figure 5) and low emitters and for exporters with different levels of environmental quality. The big emitters pollute the environment with more than 5,000 Mt CO_2eq greenhouse gas emissions per year. As for the environmental quality, the 2020 Environmental Performance Index (EPI) of the Yale University classifies countries in low (EPI below 33) and high (EPI above 66) environmental quality (label 'high env. quality' in figure 5). Our baseline is the group of exporters with values of EPI between 33 and 66. Exporters notifying environmental measures (labelled as 'notifying env-TBT' in figure 5) are identified regardless of the notification year.

Figure 5. Heterogeneity analysis by countries facing environmental technical measures (i.e., exporters).



Notes: Ordinary Least Square estimates of environmental TBT (Env-TBT) and of environmental TBT interacted with exporters' groups. The dependent variable is the natural logarithm of bilateral trade values. All specifications include dummy variables proxying the presence of at least one TBT by type, (the natural logarithm of the) *ad valorem* tariff, a dummy variable indicating the presence of trade agreements between partners, a set of fixed effects (omitted in the figure). Squares are point estimates and vertical lines are their 95-percent confidence intervals. Exporters are classified as high income according to the World Development Indicators of the World Bank. Big emitters are exporters with total greenhouse gas emissions (GHG) higher than 5,000 Mt CO_2eq. Exporters are classified in countries with high environmental quality according to the Environmental Performance Index (EPI) of the Yale University. Exporters notifying environmental TBT are identified regardless of the notification year.

Consistent with findings from Bratt (2017), we find that the distributional effects of technical measures on exporters' traded values are so divergent to be opposite: positive for selected countries and negative for others. We observe a pro-trade effect for countries affected by environmental measures. Developed exporters, such as high-income countries or members of the G20, as well as the notifying countries benefit from the presence of technical measures, as shown by the positive effects that environmental measures tend to have on their exports. The similarity of results between high income and G20 countries is partially explained by the similar composition of the two groups of countries: 69 percent of the high income countries are in the G20[29], and 74 percent of the G20 countries are high income countries[30].

29 High income countries not members of G20 are the United Arab Emirates, Bahrain, Brunei Darussalam, Chile, Iceland, Israel, Kwait, Norway, New Zealand, Oman, Quatar, Singapore, Switzerland, Uruguay.

30 G20 countries not classified as high income countries are Argentina, Bulgaria, Brazil, China, India, Indonesia, Mexico, Romania, Russian Federation, South Africa, Turkey.

Countries with better technical and financial means are likely to easily comply with measures (i.e., they are able to produce and sell products at competitive prices), gaining a comparative advantage (e.g., de Melo and Solleder, 2020).

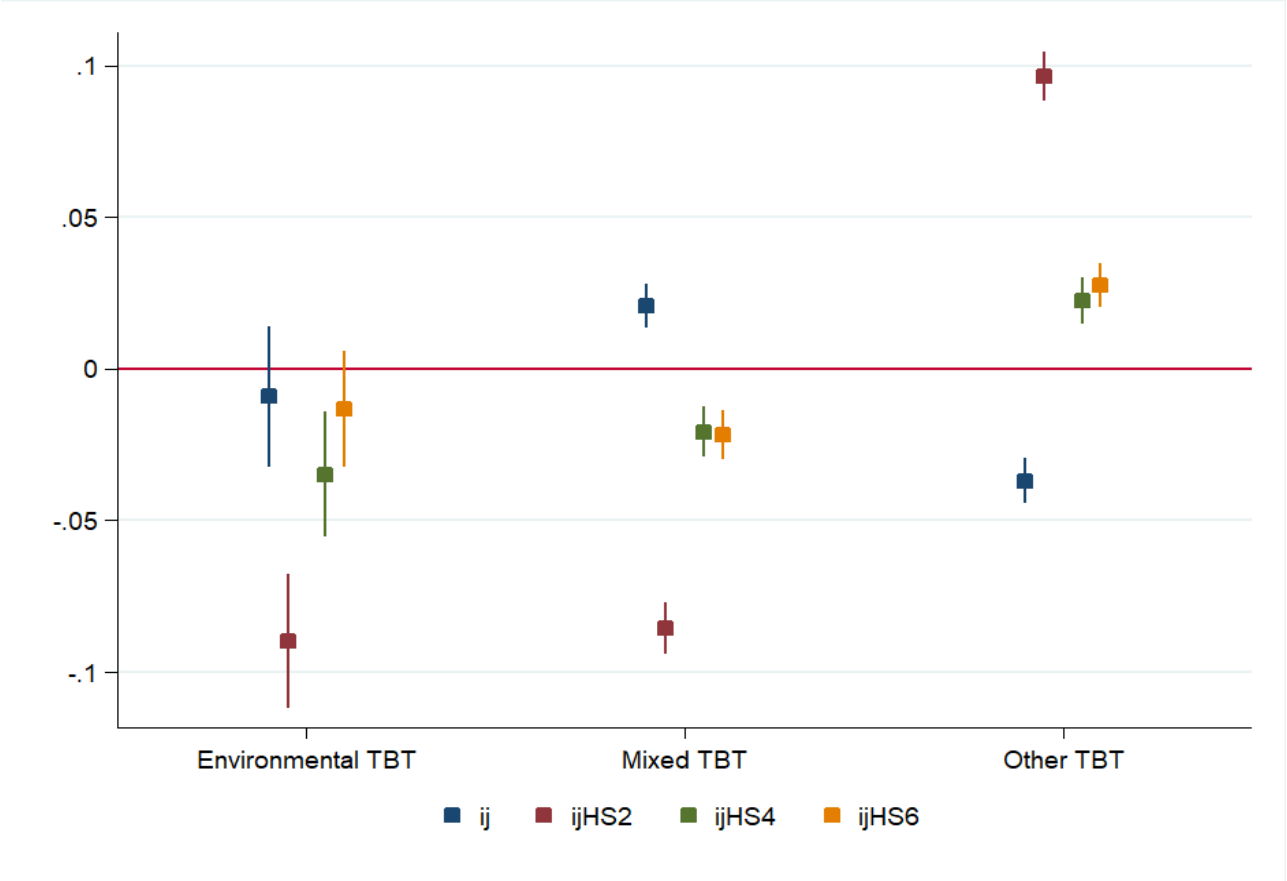
Higher levels of emissions in the exporting countries are associated with positive effect of the environmental measures. The levels of environmental quality also matter: trade from 'clean' countries (i.e., characterised by high levels of environmental quality) is favoured, while the opposite is true for 'dirty'. This evidence suggests lower competitiveness of the countries that have low environmental quality standards, due to higher compliance costs to implement greener production techniques (e.g., de Melo and Solleder, 2020; Pegels and Altenburg, 2020).

4.2.3. Sector-specific heterogeneity

While a gravity-based empirical framework has a strong explanatory power of bilateral trade flows, some bilateral heterogeneity remains unobserved (Yotov et al., 2016). Omitted variables bias may induce potential correlation between the gravity equation's error term and the variables proxying technical measures, the latter becoming econometrically endogenous. To deal with the endogeneity due to potentially omitted variables, we use bilateral fixed effects, as extensively discussed in Section 3. They account for unobservable time-invariant bilateral components (Egger and Nigai, 2015) and for unobservable linkages between the endogenous trade policy covariates and the error term (Baier and Bergstrand, 2007).

Diverse bilateral fixed effects allow us to identify different effects of environmental measures. The estimates are in figure 7 (and in table D.5 in the Appendix D) and trade volume effects in table 8. The benchmark specification with country-pair fixed effects (*ij* in figure 6, column 1 in table 8 and table D.5) allows us to rely on cross-product-time variation. Given this identification strategy, the estimated coefficients are to be interpreted as the average change in annual bilateral trade caused by the introduction of at least one environmental measure on different products. Differently, we capture the annual change in bilateral trade caused by the introduction of at least one environmental measure within a sector, through sectoral bilateral fixed effects (*ijHS2* and *ijHS4* in figure 7, columns 2 and 3 in table 8 and table D.5), and on a representative product, through country-pair-product fixed effects (*ijHS6* in figure 7, column 4 in table 8 and table D.5). This set of fixed effects controls for cross-sector and cross-product heterogeneity that may affects technical measures negotiated and applied at the sector and product levels (e.g., Yotov et al., 2016).

Figure 6. Annual change in bilateral trade, by sectoral aggregations.



Notes: Ordinary Least Square estimates of environmental, mixed, and other TBT. The dependent variable is the natural logarithm of bilateral trade values. All specifications include dummy variables proxying the presence of at least one TBT by type, (the natural logarithm of the) *ad valorem* tariff and a dummy variable indicating the presence of trade agreements between partners (omitted in the figure), but different fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), sector at the 2-digit (*HS2*) and 4-digit (*HS4*), product at the 6-digit (*HS6*) of the Harmonised System. Squares are point estimates and vertical lines are their 95-percent confidence intervals. Estimates for environmental TBT in specifications *ij* (blue) and *ijHS6* (orange) are not statistically significant.

Table 8. Trade volume effects (TVE) of technical measures.

	(1)	(2)	(3)	(4)
Variable	*ij*	*ijHS2*	*ijHS4*	*ijHS6*
Environmental TBT	0	-8.6	-3.4	0
Mixed TBT	+2.1	-8.2	-2.0	-2.2
Other TBT	-3.6	+10.1	+2.3	+2.8

Notes: Trade volume effects are in percentage and reported for statistically significant coefficients of TBT notified for environmental objectives (TBT environment), both environmental and other non-trade policy objectives (TBT mixed), and non-trade policy objectives other than the environmental protection (TBT other). Coefficients estimates are from specifications that control for different bilateral fixed effects: acronyms are implementing/importing country (*i*), affected/exporting country (*j*), sector at the 2-digit (*HS2*) and 4-digit (*HS4*), product at the 6-digit (*HS6*) of the Harmonised System.

The effect of environmental measures is progressively reduced as soon as the sources of time invariant heterogeneity are accounted for: from an 8.6 percent reduction within broader sectors (i.e., defined at the HS2-digit) to a 3.4 percent reduction within narrower sectors (i.e., defined at the HS4-digit) (figure 7). As expected, we find a larger effect when we rely on variations within broader than narrower sectors. The average change in annual bilateral trade is larger when the importing country implements at least one environmental measure on products within a HS2-digit sector than on products within a HS4-digit sector.

Consider, as an example, the trade relationship between the United States and Canada, which traded (between 2010 and 2020), 64 million dollars each year, on average. About one third of the traded value was regulated by environmental measures and interested the sectors of trees and plants (HS: 06, 23 million dollars per year), oil seeds and oleaginous fruits (HS: 12, 27 million dollars per year), mineral fuels (HS: 27, 40 million dollars per year), inorganic chemicals (HS: 28, 2 million dollars per year), soap (HS: 34, 3 million dollars per year) and chemical products (HS: 38, 11 million dollars per year). The effect of having environmental measures on products within the sector of oil seeds and oleaginous fruits[31] generates an average decline of 8.6 percent in the annual trade between the United States and Canada, quantifiable in 2 million dollars per year (on average). However, an environmental measure produces an annual reduction of 3.4 percent in the annual trade of specific subsectors with highly differentiated impacts in monetary terms, ranging from average losses varying between 400 and 500 thousand dollars for rape seeds and soya beans sectors to average losses greater than 1 million dollars in the sector of forage products.

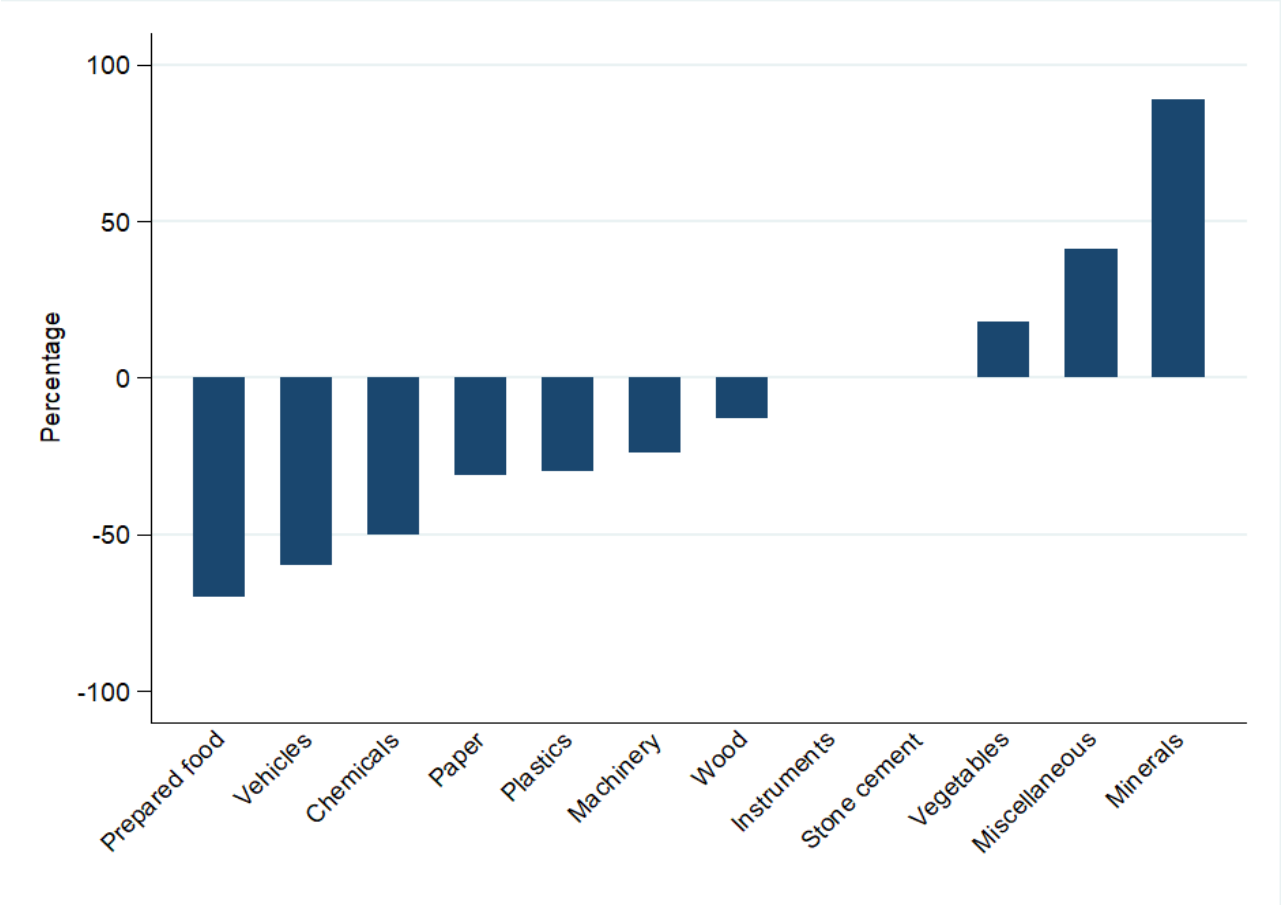
This product-composition effects signal that technical measures may impact differently markets with more sensitive products than markets with less sensitive products (Dolabella, 2020). The heterogenous effect of environmental measures across sectors is summarised in figure 7 which shows the trade volume effect (TVE) for each sector (estimates are reported in table D.6 and figure D.1 of the Appendix D)[32]. Apart for vegetables, miscellaneous and minerals, environmental measures tend to have an anti-trade effect, that is more marked for prepared food, vehicles, and chemicals in terms of trade volume effects (respectively -70, -60, -50 percent, figure 7 and table E.1 in the Appendix E[33]).

31 The HS: 12 is the only HS2-digit sector including diverse HS4-digit sectors regulated by environmental measures in the trade relationship between the United States and Canada during 2010-2020. The HS4-digit sectors affected are soya beans (HS: 1201, 15 million dollars per year), linseed (HS: 1204, 85 million dollars per year), rape seeds (HS: 1205, 13 million dollars per year), sunflower seeds (HS: 1206, 20 million dollars per year), other oil seeds and oleaginous fruits (HS: 1207, 22 million dollars per year), flours and meals of oil seeds and oleaginous fruits (HS: 1208, 4 million dollars per year), seeds, fruit and spores (HS: 1209, 9 million dollars per year), hop cones (HS: 1210, 224 thousand dollars per year), plants and parts of plants including seeds and fruits (HS: 1211, 2 million dollars per year), locust beans, seaweeds and other algae, sugar beet, sugar cane (HS: 1212, 10 million dollars per year), cereal straw and husks (HS: 1213, 5 million dollars per year), swedes, mangolds, fodder roots, hay, lucerne, clover, sainfoin, forage kale, lupines, vetches and similar forage products (HS: 1214, 33 million dollars per year).

32 The same analysis is conducted on traded values. The results are reported in table D.7 and figure D.2 of the Appendix D.

33 The table E.1 in the Appendix E also shows the annual bilateral *ad valorem* equivalent (AVE) of environmental measures at the sector *s* level, following the approach described in Kee et al. (2008) and Ghodsi and Stehrer (2022). The sector-specific AVE are computes as the ratio between the sector-specific TVEs and the sectoral distribution of tariff-based product-level trade elasticities estimated in Fontagné et al. (2022).

Figure 7. Cross-sector heterogeneity of environmental technical measures.



Notes: Trade volume effects (TVE) are in percentage and reported for statistically significant coefficients of TBT notified for environmental objectives.

Figure 6 shows the trade volume effects of technical measures notified not only for environmental reasons (i.e., mixed TBT) as well the effects of measures implemented for other reasons (i.e., other TBT).

A side evidence of the analysis is the clear trade impeding effect of the environmental measure vis-à-vis the unstable effects of technical measures pursuing multiple non-trade policy objectives. The barrier effect of the technical measures notified for both environmental and other non-trade policy objectives switch to a positive effect when we rely on within sector and time variation of technical measures. Similarly, technical measures pursuing non-trade policy objectives other than the protection of the environment, such as cost saving and productivity enhancement or quality requirements, show mixed effects on trade.

Overall, the trade outcomes tend to be related to the objective of the technical measures. Objectives of a political nature are pursued by measures related to civil and political rights and to security issues, whereas economic objectives are encompassed in measures addressing economic and social rights and environmental protection (Borchert et al., 2021; Ferrari et al., 2021). While new measures notified uniquely with environmental purposes tend to have an anti-trade effect, the measures that address a mix of objectives have heterogenous effects. While pushing for higher environmental standards to ensure equal conditions between domestic and foreign producers, the notifying countries face conflicting interests: on one side they aim to protect the environment, on the other hand they may be pushed by commercial interests (e.g., cost saving and productivity enhancement, quality requirements). These contrasting goals would explain the mixed effects we observe for mixed and other TBT.

Our results add more insights to the early paper by Fontagné et al. (2005b) as well as to the recent evidence provided by Cadot et al. (2018) and Dolabella (2020) who conclude on the restrictive effects of TBT. We argue that the trade effects of the technical measures cannot be isolated from the nature of the objectives being pursued (Schlueter et al., 2009). In short, we argue that while the overall effect is against trade, there are specific dimensions capable of explaining the heterogeneous evidence across countries and sectors affected by measures.

5. Conclusion and implications

The technical measures notified under the WTO TBT Agreement may target one (e.g., protection of the environment) or multiple objectives (e.g., economic, social and political rights, environmental protection, security issues) (Borchert et al., 2021; Ferrari et al., 2021). The non-trade policy objectives may be as relevant as the trade goals and contribute to shape trade patterns (Schlueter et al., 2009).

We proved that environmental measures naturally hinder bilateral trade flows, but a marked heterogeneity is evident across countries and sectors. The environmental measures tend to favour flows originating in trading partners with solid economic and political influence, such as the most developed economies, the members of the G20 countries. Wealthier and more industrialised countries may have better financial and technical means to comply with requirements of technical measures (e.g., Bao and Qiu, 2012; de Melo and Solleder, 2020) and therefore the environmental technical measures tend to favour reciprocal trade. Is this suggesting that the environmental measures may foster the formation (and consolidation) of a 'club effect'? We cannot answer the question, but leave this inquiry open for further research and policy analyses. We can certainly suggest that the effects of these measures are homogenous across countries that share a vision for the environment and are more active in regulating against the depletion of the environment.

Our investigation falls short of being conclusive on aspects of the political economy of regulations and calls for a deeper analysis on the vested interest that may promote the adoption of the environment related technical measures.

A bright spot is the strategic setting that technical measures, raised for the environmental protection, create in the international context. By mimicking the structure of climate clubs (e.g., Nordhaus, 2021), environmental measures offer countries the opportunity to undertake the level of environmental protection, dictated by the measure, to improve their own trade performances.

In this regard, the 'special and differential treatment' clause of the WTO, and of the General Agreement on Tariffs and Trade (GATT) before, for less developed countries assumes a particular relevance (e.g., Hoekman and Holmes, 1999; Hoekman and Nicita, 2018): developing countries may suffer the imposition of environmental measures. Failure to comply with the standard of environmental regulations, may be incentivised to specialise in the production and trade toward dirty goods, materialising the threats of the pollution heaven hypothesis.

The quote of Ursula von der Leyen, during her presidency of the European Commission, stresses the need to "*use trade tools to support sustainable development [… and] monitor the implementation of climate, environmental and labour protections*"[34]. Leveraging on non-trade policy objectives may help reaching transnational objectives, such as the protection of the environment (Jakob et al., 2022). Nevertheless, the distortive nature of the trade policy, against clean sectors and in favour of dirty industries (Shapiro, 2021; Copeland et al., 2022), and the threats for the existing divide call for continuous international cooperation and further research in this direction.

34 Mission Letter of Ursula von der Leyen, President of the European Commission, to Phil Hogan, Commissioner for Trade, Brussels, 1 December 2019. Available at https://ec.europa.eu/commission/commissioners/sites/default/files/commissioner_mission_letters/mission-letter-phil-hogan-2019_en.pdf (accessed on March 09, 2023).

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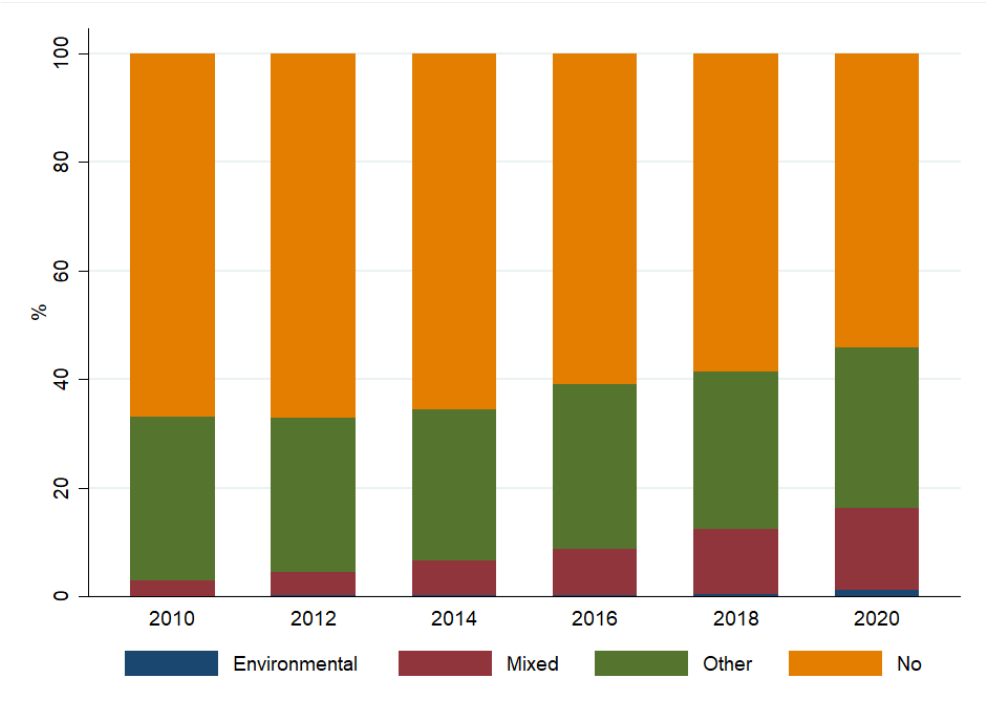
A. Stylised facts

Table A.1. Examples of environmental, mixed, and other TBT.

Non-trade policy objectives	Country-sector-year (examples)	Category
Protection of the environment	United States, fertilisers, 2013 Canada, beverages, 2016 Japan, plastics, 2019	Environmental TBT
Protection of the environment Protection of animal or plant life or health Quality requirements	China, fertilisers, 2019	Mixed TBT
Protection of the environment Consumer information, labelling Harmonisation	Singapore, machinery, 2016 Australia, machinery, 2018 New Zealand, machinery, 2019	Mixed TBT
Quality requirements Cost saving and productivity enhancement	China, vehicles, 2020 Uganda, cocoa, 2020	Other TBT
Consumer information, labelling Prevention of deceptive practices Harmonisation Reducing trade barriers and facilitating trade	United States, beverages, 2019	Other TBT

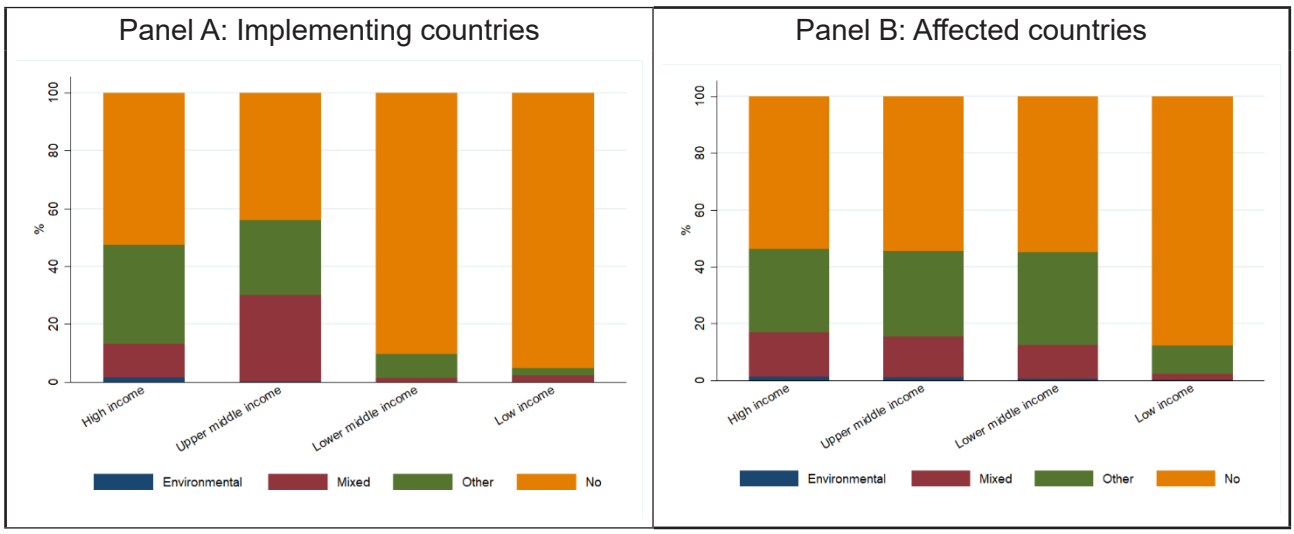
Source: WTO TBT IMS.

Figure A.1. Share of trade values regulated by technical measures, 2010-2020.



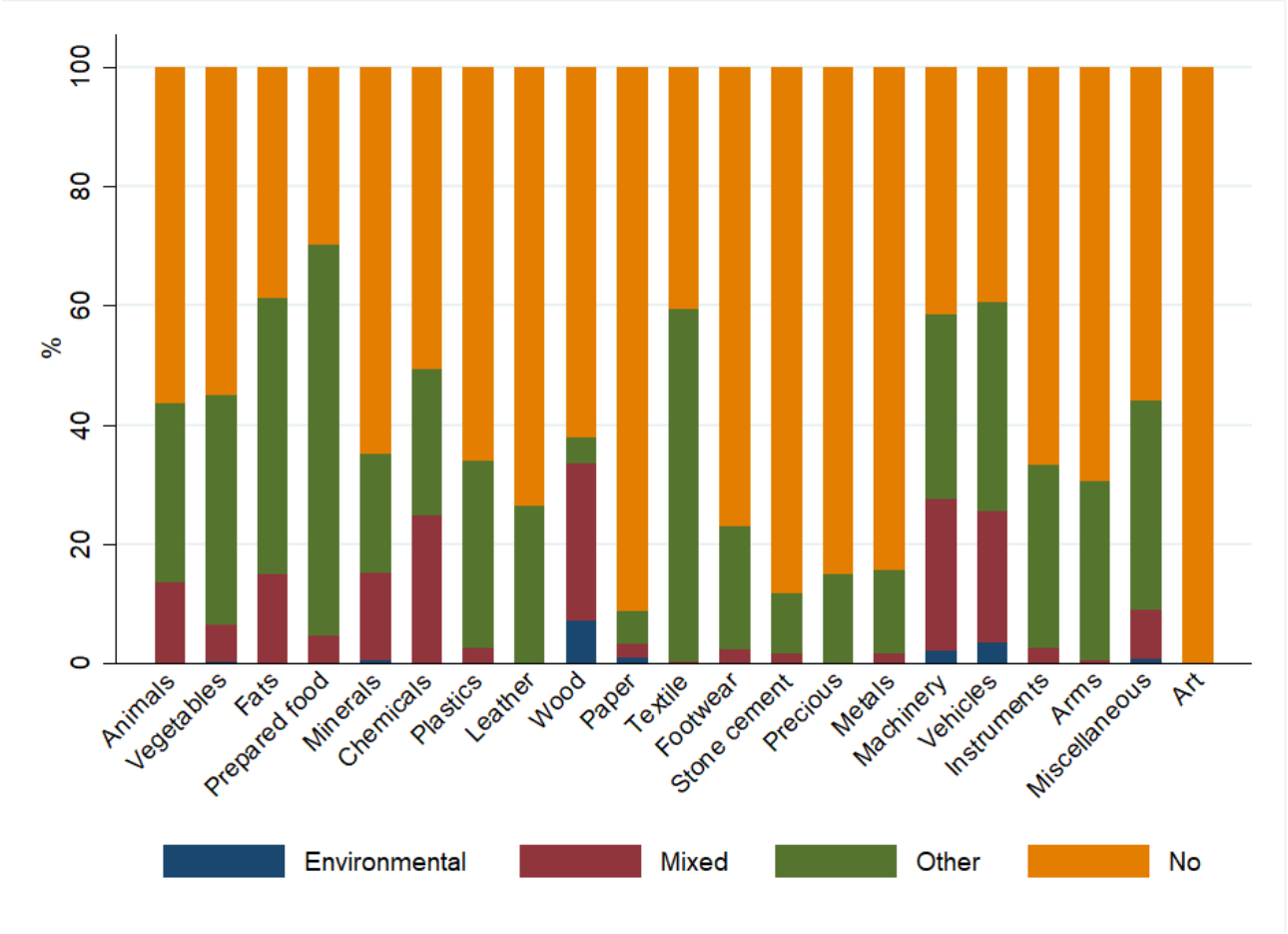
Source: Authors' elaboration on WTO TBT IMS and BACI.

Figure A.2. Share of trade values regulated by technical measures by groups of countries, 2020.



Source: Authors' elaboration on WTO TBT IMS and BACI.

Figure A.3. Share of trade values regulated by technical measures by sectors, 2020.



Source: Authors' elaboration on WTO TBT IMS and BACI.

B. Dealing with collinearity of multilateral resistance

In the gravity equation, the multilateral resistance terms are theoretical constructs, proxying the competitiveness of trading partners (Anderson and van Wincoop, 2003). Properly controlling for multilateral resistances allows to avoid the "Gold Medal Mistake"[35], evoked by Baldwin and Taglioni (2006).

The literature suggests fixing the problem using directional fixed effects (i.e., exporter and importer) in cross-section estimations (e.g., Feenstra, 2016) and time-varying directional fixed effects in a dynamic panel data framework (e.g., Olivero and Yotov, 2012).

However, the multilateral resistances are sector specific. From an empirical perspective, a proper treatment of these terms requires exporter-product-time (i.e., a_{ikt}) and importer-product-time (i.e., a_{jkt}) fixed effects (Yotov et al., 2016). Yet, fixed effects, tracking over time the sector specific competitiveness of importing countries, have the same dimensions of proxies used for technical measures (i.e., importer-product-time). This may induce collinearity problems in the estimation of the gravity equation. We run a sensitivity analysis to avoid collinearity issues and capture the effect of technical measures that vary on an importer-product-time basis.

Our baseline approach consists in excluding the product dimension *k* from demand-side fixed effects (i.e., a_{jt}, as in equation 1). This specification controls for the average competitiveness of importing countries and left unexplored the sector specific component of the multilateral resistance.

We then apply the two-step fixed effects estimator proposed by Honoré and Kesina (2017) to account for the time-varying sector specific competitiveness of importing countries. As first step, we regress bilateral trade flows against unobserved time-varying determinants of trade, that are the multilateral resistance terms (equation A.1). This step allows us to remove the variability associated with time-varying directional fixed effects and to calculate the dependent variable of the second step model, that is bilateral trade flows net of the variability of multilateral resistances (i.e., $Y_{ijkt} - (\widehat{\alpha_{\imath kt} + \alpha_{jkt}})$). As second step, net bilateral trade flows are regressed against observed time-varying determinants of trade (i.e., proxies of technical measures, ad valorem tariffs, and trade agreements) and unobserved time-invariant controls (i.e., bilateral fixed effects) (equation A.2).

$$Y_{ijkt} = \alpha_{ikt} + \alpha_{jkt} + \nu_{ijkt} \quad \text{(A.1)}$$

$$Y_{ijkt} - (\widehat{\alpha_{\imath kt} + \alpha_{jkt}}) = \alpha_{ij} + \beta \boldsymbol{TBT}^{z}_{jkt} + \gamma AVE_{ijkt} + \delta RTA_{ijt} + \upsilon_{ijkt} \quad \text{(A.2)}$$

The approach of proposed by Honoré and Kesina (2017) allows us to explain (in the second step, equation A.2) the importer-product-time technical measures net of the variability captured (in the first step, equation A.1) by importer-product-time fixed effects.

35 The "Gold Medal Mistake" is the omission of multilateral resistances (Baldwin and Taglioni, 2007).

Table B.1. Dealing with multilateral resistances and reverse causality of environmental technical measures.

	(1)	(2)
Variable [coefficient]	Current and future TBT	Current, future, past TBT
TBT_{jkt}^{env} [$\hat{B}^{env}$]	-0.2194***	-0.3854***
	(0.0248)	(0.0310)
TBT_{jkt+1}^{env} [$\hat{B}^{env}$]	0.4634***	0.6775***
	(0.0142)	(0.0169)
TBT_{jkt-1}^{env} [$\hat{B}^{env}$]		-0.1905***
		(0.0298)
TBT_{jkt-2}^{env} [$\hat{B}^{env}$]		0.2300***
		(0.0338)
TBT_{jkt}^{env} [$\hat{B}^{mixed}$]	0.6786***	0.2702***
	(0.0066)	(0.0091)
TBT_{jkt+1}^{env} [$\hat{B}^{other}$]	-0.0604***	0.1117***
	(0.0056)	(0.0077)
TBT_{jkt-1}^{env} [$\hat{B}^{mixed}$]		0.1126***
		(0.0110)
TBT_{jkt-2}^{env} [$\hat{B}^{mised}$]		0.1706***
		(0.0096)
TBT_{jkt}^{env} [$\hat{B}^{other}$]	-0.5723***	-0.5393***
	(0.0066)	(0.0085)
TBT_{jkt+1}^{env} [$\hat{B}^{mixed}$]	0.0953***	0.1244***
	(0.0053)	(0.0068)
TBT_{jkt-1}^{env} [$\hat{B}^{other}$]		-0.0707***
		(0.0093)
TBT_{jkt-2}^{env} [$\hat{B}^{other}$]		-0.0356***
		(0.0111)
AVE_{ijkt}[Y^]	-2.5910***	-2.2416***
	(0.0160)	(0.0203)
RTA_{ijkt}[δ]	0.1218***	-0.1413***
	(0.0026)	(0.0042)
Dependent variable	$\ln v_{ijkt} - (\widehat{\alpha_{ikt} + \alpha_{jkt}})$	$\ln v_{ijkt} - (\widehat{\alpha_{ikt} + \alpha_{jkt}})$
Fixed effects	a_{ij}	a_{ij}
Observations	39,276,472	18,259,249
R^2	0.21	0.20

Notes: Ordinary Least Square estimates of gravity equations (in two-step). The dependent variable is the natural logarithm of bilateral trade values net of the variability of multilateral resistances. Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*), a dummy variable indicating the presence of trade agreements between partners, and fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), product at the 6-digit of the Harmonised System (*k*), year (*t*). Zero trade flows are excluded. Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

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c. Dealing with endogeneity through an instrumental variable approach

Technical measures and bilateral trade flows are jointly determined if there is simultaneity between them, such that the notification of measures causes trade levels, and trade levels causes the notification of measures. An example of simultaneity is the magnitude of exports of a market (i.e., country, sector) and its tendency to notify technical measures.

The potential simultaneity between trade policies and trade flows is a well-known issue in the literature on international trade. In an article published in the Journal of Political Economy in 1993, Daniel Trefler claimed that the impacts of trade policies, estimated in previous studies ignoring the simultaneity between trade flows and policies, are biased downward. A few years later, Lee and Swagel (1997) argued that, despite protection through trade regulations clearly affects trade flows, trade patterns influence the structure of protection. Both studies by Trefler (1993) and Lee and Swagel (1997) demonstrate that previous estimates of the effects of trade policies, treated as given (i.e., exogenous), had been considerably underestimated. Since these seminal articles, the endogeneity issue has been treated with standard instrumental variable (IV) approaches in cross-sectional settings. For instance, Trefler (1993) finds a trade effect ten times larger when trade regulations are modelled endogenously than when they are treated exogenously; Essaji (2008) finds an impact of technical regulations on trade only when the endogeneity is accounted for. The IV approach has been frequently adopted in cross-section trade analyses to isolate the effect of trade agreements (e.g., Baier and Bergstrand, 2002; 2004; Magee, 2003; Egger et al., 2011). However, Ghosh and Yamarik (2004) demonstrated the fragility of the effects estimated using IVs with cross section data.

We implement the IV approach in a panel setting. Correcting for the potential endogeneity of technical measures, through the IV approach, requires the identification of an instrument that is correlated with technical measures, but is uncorrelated with trade-related factors that potentially affect technical measures for each country-pair-product in a certain year (i.e., the instrument and the error term are uncorrelated). As suggested in Essaji (2008), lagged values of technical measures are plausible instruments.

We construct lagged inventory measures, that are frequency index and coverage ratio of technical measures, following the approach used in Gourdon (2014) and Disdier and Fugazza (2020).

The frequency index provides the share of products affected by one or more technical measures :

$$F_{jt-1}^{TBT_{jkt}^{z}} = \left[\frac{\left(\sum_j TBT_{jt-1}^{z} M_{jt-1}\right) - TBT_{jkt-1}^{z} M_{jkt-1}}{\left(\sum_j M_{jt-1}\right) - M_{jkt-1}}\right] * 100 \quad \text{(A.3)}$$

$$F_{kt-1}^{TBT_{jkt}^{z}} = \left[\frac{\left(\sum_k TBT_{kt-1}^{z} M_{kt-1}\right) - TBT_{jkt-1}^{z} M_{jkt-1}}{\left(\sum_k M_{kt-1}\right) - M_{jkt-1}}\right] * 100 \quad \text{(A.4)}$$

where TBT_{jt-1}^{z} and TBT_{kt-1}^{z} are dummy variables reflecting the presence of one or more TBT of type *z* on imports of *j* and *k* respectively the year *t-1*; M_{jt-1} and M_{kt-1} are dummy variables indicating whether there are imports of *j* and *k* respectively the year *t-1*; we exclude the considered *k* product from the computation (i.e., $TBT_{jkt-1}^{z} M_{jkt-1}$ and M_{jkt-1}), so that the instrument has the same dimension than the technical measure.

The coverage ratio reports the share of imports affected by one or more technical measures in total imports:

$$C_{jt-1}^{TBT_{jkt}^{z}} = \left[\frac{(\sum_j TBT_{jt-1}^{z} V_{jt-1}) - TBT_{jkt-1}^{z} V_{jkt-1}}{(\sum_j V_{jt-1}) - V_{jkt-1}}\right] * 100 \quad \text{(A.5)}$$

$$C_{kt-1}^{TBT_{jkt}^{z}} = \left[\frac{(\sum_k TBT_{kt-1}^{z} V_{kt-1}) - TBT_{jkt-1}^{z} V_{jkt-1}}{(\sum_k V_{kt-1}) - V_{jkt-1}}\right] * 100 \quad \text{(A.6)}$$

where TBT_{jt-1}^{z} and TBT_{kt-1}^{z} are defined as above; V_{jt-1}^{z} and V_{kt-1}^{z} are the value of imports of *j* and *k* respectively the year *t-1*; again we exclude the considered *k* product from the computation (i.e., $TBT_{jkt-1}^{z} V_{jkt-1}$ and V_{jkt-1}).

To instrument for the technical measures, we propose the interactions between a country-specific frequency index and product-specific frequency index (i.e., , $F_{jt-1}^{TBT_{jkt}^{z}} \times F_{kt-1}^{TBT_{jkt}^{z}}$). We apply the same interaction starting from country- and product-specific coverage ratios (i.e., $C_{jt-1}^{TBT_{jkt}^{z}} \times C_{kt-1}^{TBT_{jkt}^{z}}$). These interactions, lagged of one period, capture the joint propensity of the importing country to implement a technical measure and the propensity of a product to be affected by a technical measure.

The results of the IV estimates are in table C.1. The results are consistent with the estimates obtained with least squares.

Table C.1. Effect of instrumented environmental technical measures, small flows, small versus large flows.

Dependent variable	(1)	(2)	(3)
Variable [coefficient]	Flows (small flows included)	Small flows	Flows > 10,000 USD
TBT_{jkt}^{env} $[\hat{B}^{env}]$	-0.0420	-0.0527	0.0844***
	(0.0334)	(0.0338)	(0.0315)
TBT_{jkt}^{mixed} $[\hat{B}^{mixed}]$	0.9542***	0.6464***	0.3920***
	(0.0154)	(0.0205)	(0.0134)
TBT_{jkt}^{other} $[\hat{B}^{other}]$	-1.0515***	-0.6529***	-0.5173***
	(0.0152)	(0.0207)	(0.0128)
AVE_{ijkt} [Y^]	-2.2011***	-0.9018***	-1.2639***
	(0.0135)	(0.0098)	(0.0123)
RTA_{ijt} [δ]	-0.0241***	-0.0177***	0.0061**
	(0.0033)	(0.0042)	(0.0028)
Fixed effects	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}
Observations	38,924,119	15,755,873	22,807,796
Instruments		$F_{jt-1}^{TBT_{jkt}^{z}} \times F_{kt-1}^{TBT_{jkt}^{z}}$, $C_{jt-1}^{TBT_{jkt}^{z}} \times C_{kt-1}^{TBT_{jkt}^{z}}$	
Hansen J statistic	21,414	765	18,092
p-value of Hansen J statistic	0.00	0.00	0.00
F statistic for weak identification (Cragg-Donald or Kleibergen-Paap)	28,023	7,853	22,084
LM test statistic for underidentification (Anderson or Kleibergen-Paap)	130,993	43,630	100,994
p-value of underidentification LM statistic	0.00	0.00	0.00
Log likelihood	-8.48×10^{07}	-2.93×10^{07}	-4.02×10^{07}

Notes: Instrumental Variables (IV) estimates of gravity equations (second step). The dependent variable is the natural logarithm of bilateral trade values ($ln\ v_{ijkt}$). Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*), a dummy variable indicating the presence of trade agreements between partners, and fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), product at the 6-digit of the Harmonised System (*k*), year (*t*). Zero trade flows are excluded. Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

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D. Estimates

Table D.1. Effect of environmental technical measures on trade outcomes.

	(A)			(B)			(C)		
	Values			Volumes			Unit values		
Dependent variable	$ln\ v_{ijkt}$			$ln\ q_{ijkt}$			$ln\ uv_{ijkt}$		
	(1.a)	(2.a)	(3.a)	(1.b)	(2.b)	(3.b)	(1.c)	(2.c)	(3.c)
Variable [coefficient]	Flows (small flows included)	Small flows	Flows > 10,000 USD	Flows (small flows included)	Small flows	Flows > 10,000 USD	Flows (small flows included)	Small flows	Flows > 10,000 USD
TBT_{jkt}^{env} $[\hat{B}^{env}]$	-0.0092	-0.0948***	0.0236**	0.0244*	0.0068	0.0081	-0.0116*	-0.0812***	0.0214***
	(0.0118)	(0.0120)	(0.0112)	(0.0137)	(0.0150)	(0.0139)	(0.0066)	(0.0115)	(0.0075)
TBT_{jkt}^{mixed} $[\hat{B}^{mixed}]$	0.0208***	-0.0405***	0.0617***	0.0177***	-0.0448***	0.0455***	-0.0007	-0.0044	0.0142***
	(0.0037)	(0.0035)	(0.0037)	(0.0041)	(0.0042)	(0.0043)	(0.0019)	(0.0031)	(0.0022)
TBT_{jkt}^{other} $[\hat{B}^{other}]$	-0.0369***	0.0244***	-0.0639***	-0.0488***	0.0107**	-0.0625***	0.0146***	0.0222***	-0.0017
	(0.0038)	(0.0036)	(0.0037)	(0.0041)	(0.0042)	(0.0043)	(0.0019)	(0.0032)	(0.0022)
AVE_{ijt} $[Y\hat{}]$	-2.1924***	-0.9175***	-1.2270***	-1.9102***	-0.5727***	-1.1590***	-0.2524***	-0.3006***	-0.0701***
	(0.0113)	(0.0076)	(0.0110)	(0.0115)	(0.0087)	(0.0119)	(0.0040)	(0.0057)	(0.0051)
RTA_{ijt} $[\delta]$	(0.0026)	(0.0030)	(0.0023)	(0.0028)	(0.0034)	(0.0030)	(0.0017)	(0.0026)	(0.0021)
Fixed effects	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}
Observations	55,824,664	25,738,127	29,579,034	54,443,084	24,613,538	29,323,161	54,443,084	24,613,538	29,323,161
R^2	0.54	0.26	0.50	0.59	0.41	0.65	0.61	0.41	0.65

Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade values (v_{ijkt}) in columns (1.a), (2.a), and (3.a), volumes ($ln\ q_{ijkt}$) in columns (1.b), (2.b), and (3.b), and unit values ($ln\ uv_{ijkt}$) in columns (1.c), (2.c), and (3.c). Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*), a dummy variable indicating the presence of trade agreements between partners, and fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), product at the 6-digit of the Harmonised System (*k*), year (*t*). The number of observations in models (B) and (C) lower than in model (A) is due to the presence of missing in the variable q_{ijkt}. Zero trade flows are excluded. Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table D.2. Reverse causality of environmental technical measures.

	(A)			(B)			(C)		
	Flows (small flows included)			Smal flows			Flows > 10,000 USD		
Dependent variable	$ln\ v_{ijkt}$			$ln\ v_{ijkt}$			$ln\ v_{ijkt}$		
	(1.a)	(2.a)	(3.a)	(1.b)	(2.b)	(3.b)	(1.c)	(2.c)	(3.c)
Variable [coefficient]	Current TBT	Current and forwarded TBT	Current, forwarded, lagged TBT	Current TBT	Current and forwarded TBT	Current, forwarded, lagged TBT	Current TBT	Current and forwarded TBT	Current, forwarded, lagged TBT
TBT_{ikt}^{env} $[\hat{B}^{env}]$	-0.0092	-0.0760***	-0.1593***	-0.0948***	0.0281	-0.0748**	0.0236**	-0.1024***	-0.0853***
	(0.0118)	(0.0185)	(0.0242)	(0.0120)	(0.0239)	(0.0381)	(0.0112)	(0.0159)	(0.0203)
TBT_{jkt+1}^{env} $[\hat{B}^{env}]$		-0.0183	0.0953***		-0.1129***	-0.0521***		0.0603***	0.1039***
		(0.0118)	(0.0137)		(0.0151)	(0.0196)		(0.0103)	(0.0118)
TBT_{jkt-1}^{env} $[\hat{B}^{env}]$			0.0709***			0.1234***			0.0094
			(0.0250)			(0.0456)			(0.0204)
TBT_{jkt-2}^{env} $[\hat{B}^{env}]$			-0.0630**			0.0019			-0.0862***
			(0.0284)			(0.0512)			(0.0232)
TBT_{jkt}^{mixed} $[\hat{B}^{mixed}]$	0.0208***	0.2181***	-0.0025	0.0208***	0.1487***	-0.0272**	0.0617***	0.0772***	0.0124*
	(0.0037)	(0.0058)	(0.0081)	(0.0037)	(0.0073)	(0.0133)	(0.0037)	(0.0050)	(0.0066)
TBT_{jkt+1}^{other} $[\hat{B}^{other}]$		0.0148***	-0.0339***		-0.1885***	-0.1141***		0.0006	0.0350***
		(0.0046)	(0.0058)		(0.0059)	(0.0088)		(0.0042)	(0.0055)
TBT_{jkt+1}^{mixed} $[\hat{B}^{mixded}]$			0.0356***			0.0639***			0.0137*
			(0.0085)			(0.0147)			(0.0071)
TBT_{jkt-2}^{mixed} $[\hat{B}^{mixed}]$			0.0876***			0.0831***			0.0340***
			(0.0092)			(0.0143)			(0.0080)
TBT_{jkt}^{other} $[\hat{B}^{other}]$	-0.0369***	-0.0643***	-0.1169***	-0.0369***	-0.0530***	-0.0645***	-0.0639***	-0.0289***	-0.0846***
	(0.0038)	(0.0056)	(0.0074)	(0.0038)	(0.0071)	(0.0127)	(0.0037)	(0.0049)	(0.0061)
TBT_{jkt+1}^{mixed} $[\hat{B}^{mixed}]$		-0.1852***	-0.0463***		0.0778***	0.0693***		-0.0539***	-0.0565***
		(0.0049)	(0.0064)		(0.0056)	(0.0079)		(0.0040)	(0.0049)
TBT_{jkt-1}^{other} $[\hat{B}^{other}]$			0.0169**			0.0013			0.0041
			(0.0081)			(0.0148)			(0.0067)
TBT_{jkt-2}^{other} $[\hat{B}^{other}]$			0.0488***			-0.0257*			0.0417***
			(0.0091)			(0.0145)			(0.0080)
AVE_{ijkt} $[Y\hat{}]$	-2.1924***	-2.1306***	-2.0772***	-2.1924***	-0.8393***	-0.7944***	-1.2270***	-1.2395***	-1.2951***
	(0.0113)	(0.0131)	(0.0169)	(0.0113)	(0.0095)	(0.0150)	(0.0110)	(0.0120)	(0.0148)
RTA_{ijt} $[\delta]$	-0.0310***	-0.0276***	-0.0116**	-0.0310***	-0.0183***	-0.0216***	-0.0082***	-0.0115***	0.0124***
	(0.0026)	(0.0030)	(0.0048)	(0.0026)	(0.0038)	(0.0075)	(0.0023)	(0.0025)	(0.0039)
Fixed effects	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}
Observations	55,824,664	38,922,351	18,082,840	25,738,127	15,764,915	5,788,121	29,579,034	22,795,966	12,106,207
R^2	0.54	0.54	0.56	0.26	0.24	0.24	0.50	0.51	0.53

Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade values. Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*), a dummy variable indicating the presence of trade agreements between partners, and fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), product at the 6-digit of the Harmonised System (*k*), year (*t*). Zero trade flows are excluded. Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table D.3. PPML estimates of the effect of environmental technical measures on trade values.

	Extensive margins	Intensive margins	
	(1)	(2)	(3)
Variable [coefficient]	Flows (zero trade flows included)	Flows (small flows included)	Flows > 10,000 USD
TBT_{jkt}^{env} [$\hat{B}^{env}$]	-0.2794***	-0.2151**	-0.1769**
	(0.1053)	(0.0895)	(0.0897)
TBT_{jkt}^{mixed} [$\hat{B}^{mixed}$]	0.0444	0.0969***	0.1113***
	(0.0315)	(0.0294)	(0.0296)
TBT_{jkt}^{other} [$\hat{B}^{other}$]	-0.0308	-0.0725**	-0.0841***
	(0.0319)	(0.0299)	(0.0302)
AVE_{ijkt} [Y^]	-2.0354***	-1.7552***	-1.5869***
	(0.1477)	(0.1323)	(0.1296)
RTA_{ijt} [δ]	0.0807***	0.0693***	0.0716***
	(0.0222)	(0.0211)	(0.0219)
Dependent variable	v_{ijkt}	v_{ijkt}	v_{ijkt}
Fixed effects	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}	a_{ikt}, a_{jt}, a_{ij}
Observations	341,513,136	55,824,664	29,579,034

Notes: Poisson Pseudo Maximum Likelihood (PPML) estimates of gravity equations. The dependent variable is the bilateral trade value. Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*), a dummy variable indicating the presence of trade agreements between partners, and fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), product at the 6-digit of the Harmonised System (*k*), year (*t*). Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table D.4. Heterogeneity analysis by countries facing environmental technical measures (i.e., exporters).

Variable [coefficient]	(1) Income	(2) G20 membership	(3) Emissions	(4) Environment quality	(5) Notifications
	-0.0919***	-0.0507**	-0.1505***	-0.0595***	-0.0413***
	(0.0208)	(0.0201)	(0.0188)	(0.0179)	(0.0140)
TBT_{jkt}^{env} $[\hat{B}^{env}]$	0.1236***				
	(0.0244)				
TBT_{jkt}^{env} x $income_i^{low}$ $[\hat{B}^{env}]$	-0.0623				
	(0.0913)				
TBT_{jkt}^{env} x $G20_i$ $[\hat{B}^{env}]$		0.0627***			
		(0.0238)			
TBT_{jkt}^{env} x GHG_i^{high} $[\hat{B}^{env}]$			0.1771***		
			(0.0614)		
TBT_{jkt}^{env} x EPI_i^{high} $[\hat{B}^{env}]$				0.1128***	
				(0.0230)	
TBT_{jkt}^{env} x EPI_i^{low} $[\hat{B}^{env}]$				-0.2277***	
				(0.0577)	
TBT_{jkt}^{env} x TBT_i^{env} $[\hat{B}^{env}]$					0.1041***
					(0.0238)
TBT_{jkt}^{mixed} $[\hat{B}^{mixed}]$	0.0169***	0.0208***	0.0212***	0.0174***	0.0208***
	(0.0039)	(0.0037)	(0.0047)	(0.0038)	(0.0037)
TBT_{jkt}^{other} $[\hat{B}^{other}]$	-0.0333***	-0.0369***	-0.0350***	-0.0337***	-0.0369***
	(0.0039)	(0.0038)	(0.0048)	(0.0038)	(0.0038)
AVE_{ijkt} $[Y^{\wedge}]$	-2.1836***	-2.1924***	-2.1409***	-2.1708***	-2.1924***
	(0.0115)	(0.0113)	(0.0118)	(0.0115)	(0.0113)
RTA_{ijt} $[\delta]$	-0.0316***	-0.0312***	-0.0263***	-0.0330***	-0.0308***
	(0.0026)	(0.0026)	(0.0028)	(0.0026)	(0.0026)
Dependent variable	$ln\ v_{ijkt}$	$ln\ v_{ijkt}$	$ln\ v_{ijkt}$	$ln\ v_{ijkt}$	$ln\ v_{ijkt}$
Fixed effects	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}
Observations	53,811,600	55,824,664	43,697,493	53,762,395	55,824,664
R^2	0.54	0.54	0.54	0.54	0.54

Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade values. Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*) and a dummy variable indicating the presence of trade agreements between partners, but different sets of fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), sector at the 2-digit (*s2*) and 4-digit (*s4*) of the Harmonised System, product at the 6-digit of the Harmonised System (*k*), year (*t*). Exporters are classified in high or low income according to the World Development Indicators of the World Bank. Big emitters are exporters with total greenhouse gas emissions higher than 5,000 Mt CO_2eq. Exporters are classified in countries with high or low environmental quality according to the Environmental Performance Index (EPI) of the Yale University. Exporters notifying environmental TBT are identified regardless of the notification year. Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table D.5. Within sector heterogeneity of environmental technical measures.

Variable [coefficient]	(1) Importer-exporter FE	(2) Importer-exporter-sector (HS2) FE	(3) Importer-exporter-sector (HS4) FE	(4) Importer-exporter-product (HS6) FE
TBT_{jkt}^{env} $[\hat{B}^{env}]$	-0.0092	-0.0897***	-0.0348***	-0.0133
	(0.0118)	(0.0113)	(0.0104)	(0.0097)
TBT_{jkt}^{mixed} $[\hat{B}^{mixed}]$	0.0208***	-0.0853***	-0.0207***	-0.0218***
	(0.0037)	(0.0043)	(0.0042)	(0.0040)
TBT_{jkt}^{other} $[\hat{B}^{other}]$	-0.0369***	0.0965***	0.0225***	0.0275***
	(0.0038)	(0.0041)	(0.0038)	(0.0036)
AVE_{ijkt} $[Y\hat{}]$	-2.1924***	-1.4069***	-0.7623***	-0.4507***
	(0.0113)	(0.0125)	(0.0149)	(0.0165)
RTA_{ijt} $[\delta]$	-0.0310***	-0.0250***	-0.0217***	-0.0206***
	(0.0026)	(0.0026)	(0.0026)	(0.0025)
Dependent variable	$ln\ v_{ijkt}$	$ln\ v_{ijkt}$	$ln\ v_{ijkt}$	$ln\ v_{ijkt}$
Fixed effects	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ijs2}	a_{ikt}, a_{jk}, a_{ijs4}	a_{ikt}, a_{jk}, a_{ijk}
Observations	55,824,664	55,641,791	54,204,285	50,494,963
R^2	0.54	0.60	0.70	0.82

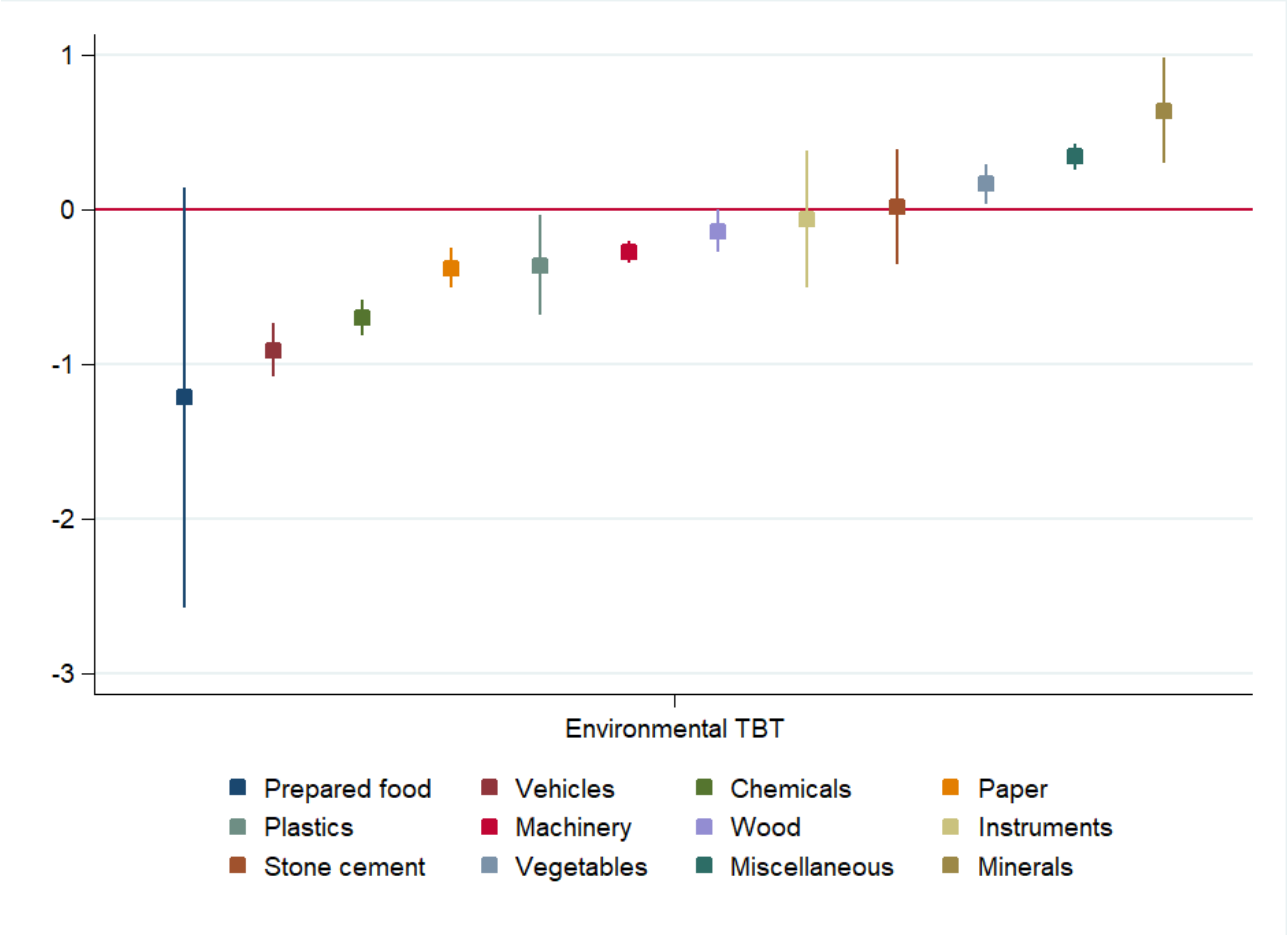
Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade values. Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*) and a dummy variable indicating the presence of trade agreements between partners, but different sets of fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), sector at the 2-digit (*s2*) and 4-digit (*s4*) of the Harmonised System, product at the 6-digit of the Harmonised System (*k*), year (*t*). Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table D.6. Cross-sector heterogeneity of environmental technical measures on trade volumes.

Variable [coefficient]	(1) Vegetables	(2) Prepared food	(3) Minerals	(4) Chemicals	(5) Plastics	(6) Wood	(7) Paper	(8) Stone cement	(9) Machinery	(10) Vehicles	(11) Instruments	(12) Miscellaneous
TBT^{env}_{jkt} [$\hat{B}^{env}$]	0.1642**	-1.2169*	0.6379***	-0.7006***	-0.3604**	-0.1376*	-0.3766***	0.0167	-0.2761***	-0.9079***	-0.0597	0.3405***
	(0.0672)	(0.6919)	(0.1734)	(0.0597)	(0.1636)	(0.0714)	(0.0654)	(0.1890)	(0.0355)	(0.0879)	(0.2259)	(0.0442)
TBT^{mixed}_{jkt} [$\hat{B}^{mixed}$]	-0.2215***	-0.1368	0.3706***	0.0783***	-0.0483	-0.1111**	0.0613	0.0105	-0.1487***	-0.6314***	0.1843***	0.0331
	(0.0825)	(0.1063)	(0.0813)	(0.0103)	(0.0343)	(0.0460)	(0.0545)	(0.0505)	(0.0075)	(0.0318)	(0.0317)	(0.0259)
TBT^{other}_{jkt} [$\hat{B}^{other}$]	0.1066	0.2395**	-0.2702***	-0.0542***	0.2447***	0.2691***	-0.1665***	-0.1050**	-0.0429***	0.5713***	-0.0441	0.0003
	(0.0826)	(0.1059)	(0.0861)	(0.0103)	(0.0342)	(0.0517)	(0.0590)	(0.0526)	(0.0075)	(0.0309)	(0.0325)	(0.0249)
AVE_{ijkt}[Y^]	-1.3430***	-0.8105***	-2.3720***	-2.6935***	-2.8381***	-3.6172***	-3.5936***	-1.5398***	-1.8107***	-3.0887***	0.1652***	-1.6301***
	(0.0402)	(0.0251)	(0.2330)	(0.0693)	(0.0548)	(0.1235)	(0.0796)	(0.0720)	(0.0279)	(0.0646)	(0.0568)	(0.0619)
RTA_{ijt}[δ]	-0.0576***	0.0200	0.0153	-0.0548***	-0.0582***	-0.0717***	-0.0114	-0.0432**	-0.0778***	-0.1142***	-0.0438***	-0.0495***
	(0.0175)	(0.0156)	(0.0391)	(0.0100)	(0.0120)	(0.0252)	(0.0170)	(0.0169)	(0.0054)	(0.0156)	(0.0097)	(0.0129)
Dependent variable	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}	ln q_{ijkt}
Fixed effects	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}
Observations	1,970,129	2,206,229	673,073	5,742,508	3,214,184	826,308	1,766,995	1,723,316	12,089,016	1,514,692	2,941,486	2,100,980
R^2	0.57	0.54	0.54	0.55	0.61	0.63	0.61	0.60	0.58	0.63	0.57	0.63

Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade volumes. Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*) and a dummy variable indicating the presence of trade agreements between partners, but different sets of fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), sector at the 2-digit (*s2*) and 4-digit (*s4*) of the Harmonised System, product at the 6-digit of the Harmonised System (*k*), year (*t*). Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level. Vegetables includes HS:06, HS:07, HS:08, HS:09, HS:10, HS:11, HS:12, HS:13, HS:14; Prepared food includes HS:16, HS:17, HS:18, HS:19, HS:20, HS:21, HS:22, HS:23, HS:24; Minerals includes HS:25, HS:26, HS:27; Chemicals includes HS:28, HS:29, HS:30, HS:31, HS:32, HS:33, HS:34, HS:35, HS:36, HS:37, HS:38; Plastics includes HS:39, HS:40; Wood includes HS:44, HS:45, HS:46; Paper includes HS:47, HS:48, HS:49; Stone cement includes HS:68, HS:69, HS:70; Machinery includes HS:84, HS:85; Vehicles includes HS:86, HS:87, HS:88, HS:89; Instruments includes HS:90, HS:91, HS:92; Miscellaneous includes HS:94, HS:95, HS:96. Animals (HS:01, HS:02, HS:03, HS:04, HS:05), Fats (HS:15), Leather (HS:41, HS:42, HS:43), Textile (HS:50, HS:51, HS:52, HS:53, HS:54, HS:55, HS:56, HS:57, HS:58, HS:59, HS:60, HS:61, HS:62, HS:63), Footwear (HS:64, HS:65, HS:66, HS:67), Precious (HS:71), Metals (HS:72, HS:73, HS:74, HS:75, HS:76, HS:77, HS:78, HS:79, HS:80, HS:81, HS:82, HS:83), Arms (HS:93), Art (HS:97), Other (HS:98, HS:99) not estimated because of collinearity.

Figure D.1. Cross-sector heterogeneity of environmental technical measures on trade volumes.



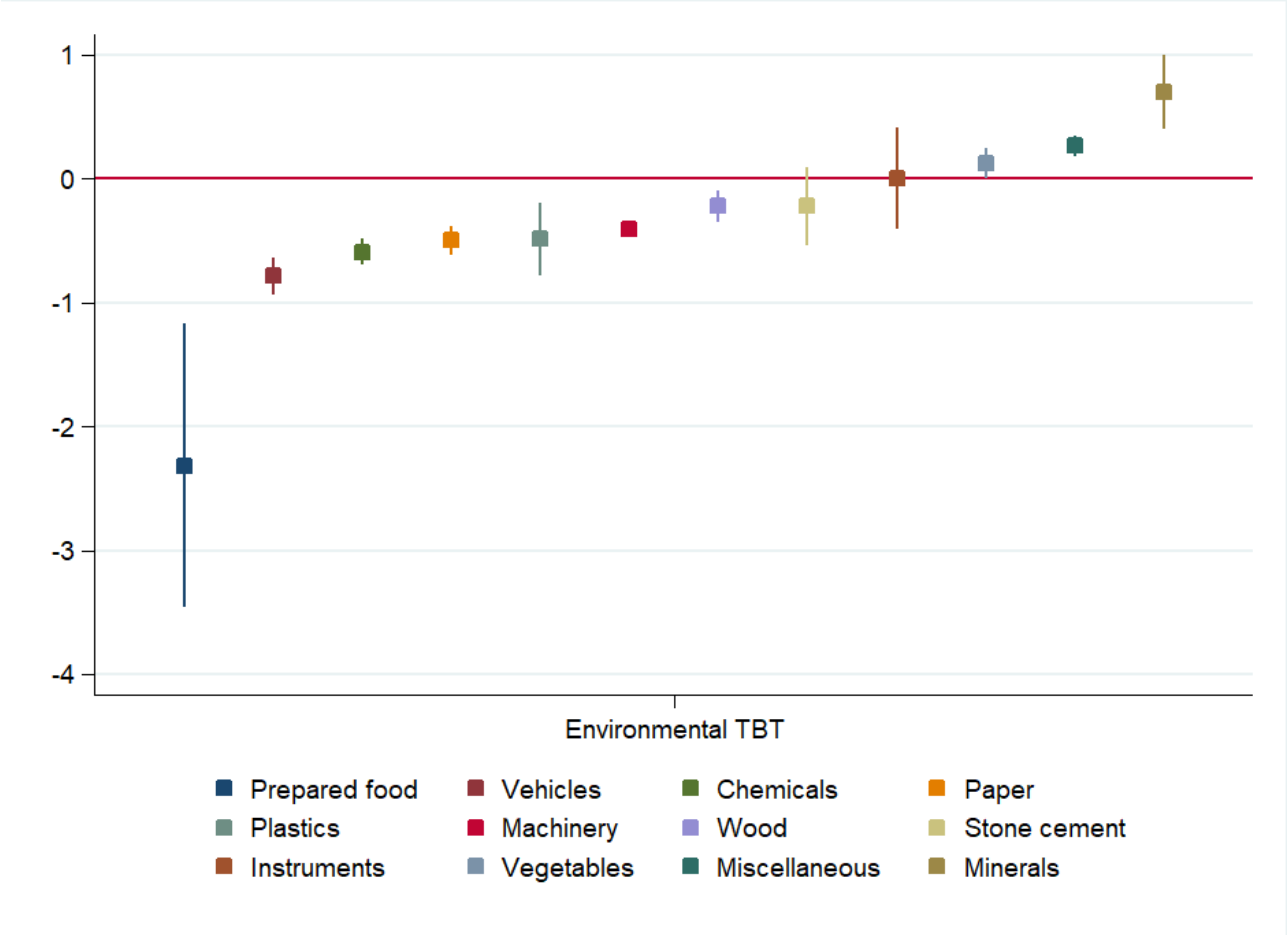
Notes: Ordinary Least Square estimates of environmental TBT. The dependent variable is the natural logarithm of bilateral trade volumes. All specifications include dummy variables proxying the presence of at least one TBT by type, (the natural logarithm of the) *ad valorem* tariff and a dummy variable indicating the presence of trade agreements between partners (omitted in the figure), and bilateral fixed effects. Squares are point estimates and vertical lines are their 95-percent confidence intervals. Estimates for stone cement (light beige) and instruments (light brown) are not statistically significant

Table D.7. Cross-sector heterogeneity of environmental technical measures on trade values.

Variable [coefficient]	(1) Vegetables	(2) Prepared food	(3) Minerals	(4) Chemicals	(5) Plastics	(6) Wood	(7) Paper	(8) Stone cement	(9) Machinery	(10) Vehicles	(11) Instruments	(12) Miscellaneous
TBT_{jkt}^{env} [$\hat{B}^{env}$]	0.1250**	-2.3151***	0.6983***	-0.5915***	-0.4862***	-0.2207***	-0.4988***	-0.2207	-0.4106***	-0.7823***	0.0013	0.2653***
	(0.0607)	(0.5855)	(0.1510)	(0.0542)	(0.1485)	(0.0659)	(0.0595)	(0.1612)	(0.0330)	(0.0762)	(0.2084)	(0.0405)
TBT_{jkt}^{mixed} [$\hat{B}^{mixed}$]	-0.2938***	-0.1405	0.2784***	0.0891***	-0.0616**	-0.1884***	0.0942*	-0.0370	-0.1940***	-0.6187***	0.1060***	0.0250
	(0.0739)	(0.0959)	(0.0663)	(0.0090)	(0.0307)	(0.0414)	(0.0528)	(0.0450)	(0.0070)	(0.0303)	(0.0314)	(0.0240)
TBT_{jkt}^{other} [$\hat{B}^{other}$]	0.1195	0.1903**	-0.2167***	-0.0274***	0.2399***	0.2851***	-0.2608***	-0.0836*	-0.0264***	0.5589***	-0.0023	0.0202
	(0.0740)	(0.0955)	(0.0702)	(0.0091)	(0.0307)	(0.0464)	(0.0571)	(0.0468)	(0.0070)	(0.0296)	(0.0322)	(0.0229)
AVE_{ijkt} [$Y^{\wedge}$]	-1.3837***	-0.7247***	-2.0082***	-2.8825***	-2.9458***	-4.0382***	-3.6394***	-1.6722***	-2.3348***	-3.2588***	-1.1781***	-1.6742***
	(0.0372)	(0.0231)	(0.1952)	(0.0696)	(0.0496)	(0.1116)	(0.0740)	(0.0622)	(0.0259)	(0.0632)	(0.0545)	(0.0597)
RTA_{ijt} [δ]	-0.0637***	0.0225	-0.0220	-0.0293***	-0.0255**	-0.0352	-0.0095	-0.0259*	-0.0417***	-0.0718***	0.0089	-0.0163
	(0.0160)	(0.0143)	(0.0324)	(0.0088)	(0.0107)	(0.0220)	(0.0155)	(0.0144)	(0.0050)	(0.0142)	(0.0094)	(0.0121)
Dependent variable	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}	ln v_{ijkt}
Fixed effects	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}	a_{ikt}, a_{jk}, a_{ij}
Observations	1,988,947	2,221,309	684,220	5,909,048	3,268,303	841,643	1,802,729	1,766,427	12,430,213	1,545,449	3,090,919	2,148,436
R^2	0.52	0.53	0.54	0.52	0.58	0.56	0.56	0.54	0.58	0.61	0.60	0.62

Notes: Ordinary Least Square estimates of gravity equations. The dependent variable is the natural logarithm of bilateral trade values. Environmental (*env*), mixed and other technical barriers to trade (TBT) modelled as dummy variables. Mixed TBT include TBT notified for both environmental and other non-trade policy objectives. Other TBT include TBT notified for non-trade policy objectives other than the environmental protection. All specifications include (the natural logarithm of the) *ad valorem* tariff (*AVE*) and a dummy variable indicating the presence of trade agreements between partners, but different sets of fixed effects. Subscripts indicate implementing/importing country (*i*), affected/exporting country (*j*), sector at the 2-digit (*s2*) and 4-digit (*s4*) of the Harmonised System, product at the 6-digit of the Harmonised System (*k*), year (*t*). Standard errors, clustered at country-pair-product level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level. Vegetables includes HS:06, HS:07, HS:08, HS:09, HS:10, HS:11, HS:12, HS:13, HS:14; Prepared food includes HS:16, HS:17, HS:18, HS:19, HS:20, HS:21, HS:22, HS:23, HS:24; Minerals includes HS:25, HS:26, HS:27; Chemicals includes HS:28, HS:29, HS:30, HS:31, HS:32, HS:33, HS:34, HS:35, HS:36, HS:37, HS:38; Plastics includes HS:39, HS:40; Wood includes HS:44, HS:45, HS:46; Paper includes HS:47, HS:48, HS:49; Stone cement includes HS:68, HS:69, HS:70; Machinery includes HS:84, HS:85; Vehicles includes HS:86, HS:87, HS:88, HS:89; Instruments includes HS:90, HS:91, HS:92; Miscellaneous includes HS:94, HS:95, HS:96. Animals (HS:01, HS:02, HS:03, HS:04, HS:05), Fats (HS:15), Leather (HS:41, HS:42, HS:43), Textile (HS:50, HS:51, HS:52, HS:53, HS:54, HS:55, HS:56, HS:57, HS:58, HS:59, HS:60, HS:61, HS:62, HS:63), Footwear (HS:64, HS:65, HS:66, HS:67), Precious (HS:71), Metals (HS:72, HS:73, HS:74, HS:75, HS:76, HS:77, HS:78, HS:79, HS:80, HS:81, HS:82, HS:83), Arms (HS:93), Art (HS:97), Other (HS:98, HS:99) not estimated because of collinearity.

Figure D.2. Cross-sector heterogeneity of environmental technical measures on trade values.



Notes: Ordinary Least Square estimates of environmental TBT. The dependent variable is the natural logarithm of bilateral trade values. All specifications include dummy variables proxying the presence of at least one TBT by type, (the natural logarithm of the) *ad valorem* tariff and a dummy variable indicating the presence of trade agreements between partners (omitted in the figure), and bilateral fixed effects. Squares are point estimates and vertical lines are their 95-percent confidence intervals. Estimates for stone cement (light beige) and instruments (light brown) are not statistically significant.

E. Ad valorem equivalent of technical measures

We derive the annual bilateral *ad valorem* equivalent (AVE) of technical measures of type *z* at the sector *s* level, following the approach described in Kee et al. (2008) and Ghodsi and Stehrer (2022). The sector-specific AVE are computes as follows: $AVE_s^z = \frac{TVE_s^z}{\epsilon_{ijs}}$. Using bilateral trade volumes as dependent variable, we run the gravity regressions for each sector, including all the products in the sectors (i.e., $\forall k \in s$), to obtain sector-specific trade volume effects, TVE^z_s. The term ε_{ijs} is the 50th percentile of the sectoral distribution of tariff-based product-level trade elasticities estimated in Fontagné et al. (2022). They identify trade elasticities at the HS6-digit product level through changes in tariffs and avoid the use of the prices of imports (i.e., unit values) potentially subject to measurement error and simultaneity bias. The trade elasticities they estimate (and used in this analysis) are based on 1 percent significant tariff elasticity.

Table E.1. Cross-sector heterogeneity of environmental technical measures.

Sector	TVE	AVE
Prepared food	-70	+12
Vehicles	-60	+5
Chemicals	-50	+4
Paper	-31	+3
Plastics	-30	+4
Machinery	-24	+3
Wood	-13	+1
Instruments	0	0
Stone cement	0	0
Vegetables	+18	-3
Miscellaneous	+41	-8
Minerals	+89	-3

Notes: Trade volume effects (TVE) and *ad valorem* equivalent (AVE) are in percentage and reported for statistically significant coefficients of TBT notified for environmental objectives. AVE are obtained as the ratio between the sectoral TVE and the 50th percentile of the sectoral distribution of tariff-based product-level trade elasticities estimated in Fontagné et al. (2022).

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