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Greening Regional Trade Agreements and Domestic Regulation

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Abstract
This paper aims at assessing whether targeted environmental provisions included in Regional Trade Agreements (RTAs) may influence the adoption of domestic regulations. Drawing on recent database about RTAs environmental provisions, we build a panel of 23 years and 142 countries and estimate their effects on the Technical Barriers to Trade (TBT) notified to the WTO by countries related to fertilizers and pesticides. Different empirical models are used, also to account for endogeneity mostly due to unobserved heterogeneity and reverse causality. We consider also endogeneity arising because TBT of one country may be influenced by those of other countries and, hence, use a spatial autoregressive model as well. Our results show that RTA provisions related to fertilizers and pesticides are effective in increasing the number of TBT on fertilizers and pesticides enacted by both developed and developing countries. Further, findings show that only for the subsample of developed countries the TBT in one country influence TBT in other countries.

Keywords Regional Trade Agreements · Technical barriers to trade · Environmental provisions

JEL Classification F13 · F14 · F18 · Q2

1 Introduction

Recent Regional Trade Agreements (RTAs) have evolved significantly beyond their original focus on tariff liberalization, now encompassing a wide range of policy areas, including competition, public procurement, investment, intellectual property rights, environmental protection, and labour standards. Since the 1990s, the inclusion of

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environmental provisions in RTAs has steadily increased, particularly in agreements between developed and developing countries. While early RTAs primarily featured broad and generic commitments to environmental protection, the past two decades have seen the incorporation of more specific provisions addressing concrete issues such as fisheries, biodiversity, greenhouse gas emissions, and deforestation (Monteiro, & Trachtman, 2020).

The growing "greening" of RTAs is often attributed to strong environmental advocacy and public support in developed countries. Civil society organizations and Non-Governmental Organizations (NGOs) have voiced concerns that RTAs contribute to environmental degradation, particularly through the intensification of agricultural trade. [1] Empirical studies lend support to this concern. For example, Longo and York (2008) find a significant correlation between export-oriented agricultural production and increased use of fertilizers and pesticides. Pendrill et al. (2019) estimate that 29% to 39% of deforestation-related emissions are linked to agricultural trade, while Abman and Lundberg (2020) document a notable rise in deforestation in the three years following the implementation of an RTA.

In this context, assessing whether environmental provisions in RTAs can effectively mitigate the negative environmental externalities associated with trade liberalization becomes highly relevant. A growing body of empirical literature has examined the impact of such provisions on various environmental indicators, including CO_2 emissions (Baghdadi et al., 2013; Martinez-Zarzoso et al., 2023; Sorgho & Tarakan, 2022; Brandi, & Schwab, 2024), air pollution (Martinez-Zarzoso & Oueslati, 2016), deforestation (Abman et al., 2024), overfishing (Bayramoglu et al., 2023), biodiversity loss (Gozlan, & Lochard, 2024), and pollution-intensive ("dirty") exports (Brandi et al., 2020). Most of these studies conclude that environmental provisions in RTAs can yield positive environmental outcomes. However, these effects are often limited to agreements containing specific and enforceable provisions, as opposed to those with only generic environmental language (Sorgho & Tarakan, 2022; Abman et al., 2024).

Notably, the effectiveness of these environmental provisions often hinges on their translation into domestic policy. For example, RTAs signed by the European Union frequently include pesticide-related provisions that oblige parties to ratify or implement international environmental agreements or to maintain a certain level of environmental protection (Velut et al., 2022). Fulfilling such commitments typically requires enacting or amending domestic legislation. Despite this, there remains limited empirical evidence on the domestic implementation of international environmental commitments. One notable exception is Brandi et al. (2019), who find that RTAs environmental provisions tend to positively influence the development of domestic environmental legislation, with the effect being more pronounced in developing countries.

[1] One recent example is the protests of May 2023 in Brussels against the EU- Mercosur trade negotiations. Activists from Greenpeace argue that this trade agreement will increase trade in agrochemicals and their use in agriculture. They have sprayed the EU Council headquarters with an agricultural pesticide pump, while EU trade ministers were discussing the EU-Mercosur trade deal. https://www.greenpeace.org/eu-unit/issues/nature-food/47322/want-to-do-something-good-for-farmers-stop-the-eu-mercosur-trade-deal/?utm_source=chatgpt.com.

This paper aims to provide empirical evidence on the impact of environmental provisions related to fertilizers and pesticides that are included in RTAs. As noted above, the implications of RTAs for agrochemical use have become a salient issue in public debate, particularly when trading partners have divergent environmental standards. For example, in the case of the EU-Mercosur agreement, a major concern is that increased imports of low-cost agricultural products from Mercosur countries—where environmental standards are generally weaker—could lead to intensified use of agrochemicals, thereby raising risks to food safety and water quality (Buczinski et al., 2023). The limited empirical evidence available to date suggests that RTAs may indeed contribute to increased agrochemical use in agriculture. Williams and Shumway (2000) estimated that the implementation of the NAFTA agreement led to a one-third increase in pesticide and fertilizer use in the United States. More recently, Nie et al. (2022) found that the China-ASEAN agreement contributed to an increase in fertilizer use in China's fresh fruit and vegetable export sector. Given that environmental provisions in RTAs must be translated into domestic regulations in order to be effective, our central research question is: Do RTA provisions on fertilizers and pesticides foster domestic regulation in these areas?

The availability and quality of data are critical for assessing the effectiveness of such provisions. Only in recent years have datasets become sufficiently detailed and comprehensive to enable robust empirical analysis across a large sample of countries and years. To construct our key variables, we rely on two complementary data sources. First, we use the WTO database of Technical Barriers to Trade (TBT) notifications. TBTs refer to regulations introduced by governments to safeguard public interests such as health, environmental protection, and animal welfare. Under the WTO TBT Agreement, member states are required to notify the WTO of technical regulations that may affect trade. In this context, the number of TBT notifications related to fertilizers and pesticides serves as a reasonable proxy for the intensity of domestic regulation in this policy domain. Second, we draw on the Trade and Environment Database (TREND), which provides granular information on nearly 300 environmental provisions across 770 RTAs, covering a wide range of years and countries. For the purposes of this study, we focus on those provisions specifically addressing fertilizers and pesticides. Our panel dataset spans 23 years (1995–2017) and includes 142 countries, providing a rich empirical foundation to investigate the extent to which environmental provisions in RTAs are associated with strengthened domestic regulation on agrochemicals.

The relationship between the environmental provisions in RTAs and TBT notifications is complex. On the one hand, it is reasonable to hypothesize - as we do - that environmental provisions in RTAs positively influence TBT notifications. When the commitments enshrined in RTAs exceed the stringency of existing domestic regulations, member countries are required to introduce new legislation to comply with such provisions. These legislative changes are, in most cases, notified to the WTO under the TBT Agreement. The extent to which governments are willing and able to translate international commitments into domestic regulatory actions depends on a range of economic, political, and institutional factors. Understanding the drivers behind the adoption of more stringent standards in the context of RTAs offers valuable insights into this process. Strong regulatory standards increase both fixed and variable compliance costs for domestic and foreign firms, resulting in two key outcomes (Disdier et al., 2015; Santeramo & Lamonaca, 2019). First, less efficient—typically smaller—firms may find it unviable to absorb the increased fixed costs, thereby leading to their exit from the market. Empirical evidence indicates that smaller exporters are disproportionately affected by stricter pesticide standards, particularly in their decisions to enter or exit international markets (Fernandes et al., 2019). Second, firms located in countries with comparatively weaker standards incur higher costs to meet the regulatory requirements of more stringent countries. Consequently, new TBT measures can lead to a redistribution of profits both within countries (from less to more efficient firms) and across countries (from low- to high-standard economies). The political economy literature suggests that the imposition of non-tariff measures, such as TBTs, is often associated with the influence of large transnational lobbies. Large firms may lobby national governments to adopt more stringent regulations that can serve as barriers to entry, thus reducing competition (Abel-Koch, 2013). Also, transnational lobbies tend to be particularly effective in countries engaged in RTAs, as they are already well-organized to influence both the negotiation and implementation phases of such agreements and are hence well-established as influential interest groups within the framework of RTAs (Hergelegiu, 2017). Accordingly, an important driver of the domestic implementation of RTA provisions on fertilizers and pesticides is the lobbying power of large firms and transnational actors.

In addition, environmental chapters in RTAs frequently include institutional mechanisms designed to promote cooperation on sustainable development and monitor the implementation of environmental commitments. These mechanisms enhance information exchange and strengthen civil society's awareness of environmental risks, thereby increasing the likelihood of new environmental regulations, especially in countries with initially weak regulatory frameworks.

However, TBTs may also serve as an important determinant of the inclusion of environmental provisions in RTAs. Countries with more extensive regulatory frameworks are generally more inclined to sign RTAs that incorporate environmental provisions—particularly when these agreements involve partners with weaker regulatory standards. This tendency is driven by both economic and political considerations. Countries with strong environmental standards seek to avoid the so-called "pollution haven" effect within RTAs, whereby trade liberalization incentivizes firms to relocate production to jurisdictions with laxer regulations in order to minimize fixed and variable costs. Additionally, these countries aim to protect their consumers from potentially unsafe food imports originating from less regulated economies. Unsurprisingly, the European Union has emerged as a leading actor in the proliferation of "green" RTAs. Furthermore, transnational lobbies advocating for stricter environmental regulation are often the same actors who support deep trade integration.

This bidirectional relationship introduces a significant source of endogeneity in empirical analysis, as it reflects reverse causality that must be carefully addressed in the econometric framework.

Timing is also likely to play a critical role in both directions of this relationship. Countries may delay or anticipate the domestic implementation of RTA commitments on fertilizers and pesticides due to institutional constraints or political deadlines which makes governments more reluctant/willing to adopt environmental regulations. Also, there may be a time lag between the introduction of a TBT and the signing of an RTA that includes environmental provisions. Finally, both TBTs and environmental provisions may exhibit persistence, in that once introduced, they tend to remain in place. This potential dynamic relationship and persistency of variables should be explicitly accounted for in empirical assessments.

In our empirical analysis, we account also for several additional determinants of TBTs that have been emphasized in the existing literature (Beverelli et al., 2014; Ghodsi, 2016; Orefice, 2017; Hergelėgiu, 2017; Cha, & Koo, 2021). The first is tariffs. Since TBTs affect both the fixed and variable costs of trade, they can function as non-tariff measures. It has been widely documented that TBTs may emerge as a response to tariff liberalization, effectively serving as substitutes for tariff-based protectionism. Second, the perception of health and environmental risks constitutes a legitimate rationale for the adoption of more stringent regulations, particularly in the production and use of fertilizers and pesticides. Third, regulatory frameworks in one country may be influenced by those in other countries. Governments may choose to voluntarily harmonize their domestic regulations with those of their trading partners to enhance the international competitiveness of domestic firms. [2] In light of these considerations, we also incorporate potential spatial determinants of environmental TBTs into our analysis, recognizing that regulatory diffusion across countries may play a significant role.

We contribute to different strands of the existing literature. First, we complement the literature on the determinants of TBT from two points of view: *i*) by introducing a new explanatory variable - the presence of environmental provisions in RTAs - which may incentivise the adoption of domestic regulation; *ii*) by considering the potential spillover effects of TBTs across countries, whereby the implementation of TBTs in one country may influence the adoption of similar measures in others. Second, we contribute to the emerging body of literature assessing the impact of specific environmental provisions of RTAs. To the best of our knowledge, the issue of fertilizers and pesticides has not yet been explored (Abman et al., 2024; Bayramoglu et al., 2023; Gozlan & Lochard, 2024; Brandi & Morin, 2023). Furthermore, we contribute to improve our understanding of how international environmental commitments influence domestic regulatory outcomes, thereby contributing to the broader literature on the interplay between international agreements and national policy frameworks (Brandi et al., 2019).

The remainder of this paper is organized as follows. The next section explains the data used, and the third illustrates our empirical strategy. The fourth section discusses the results, while the final one offers concluding remarks.

[2] Cha and Koo (2021) have shown that because of strict EU regulations on chemicals, several exporting countries have harmonized their legislation to that of the EU.

2 Data

2.1 TBT

According to the WTO Agreement on TBTs, member countries are required to notify any technical regulations that may affect international trade. Technical standards concerning the production and use of fertilizers and pesticides are often introduced with the primary objectives of protecting human health and the environment. These standards typically apply equally to domestically produced and imported goods. For example, the European Union's REACH program (Registration, Evaluation, Authorisation and Restriction of Chemicals) imposes obligations on both manufacturers and importers. Consequently, any regulations adopted under such frameworks should, in principle, be notified to the WTO as TBTs. [3]

In this context, we consider TBT notifications a reasonable proxy for the presence and evolution of domestic regulatory activity related to agrochemicals. To construct our dataset, we initially identified all TBT notifications submitted to the WTO that relate to the regulation of fertilizers and pesticides. [4] Our data reveal a total of 1,813 such TBTs.

Using this information, we developed a balanced panel dataset covering 142 countries over the period from 1995 to 2017. During this timeframe, the number of TBT notifications concerning fertilizers and pesticides increased significantly. Although the share of developing countries in total TBT notifications was relatively low at the beginning of the period—around 2% in 1995—it rose steadily to 21% by 2017 (see Fig. 1). Notably, Brazil alone accounted for approximately one-sixth of developing-country notifications in 2017. Among developed economies, the European Union accounted for about 56% of total TBT notifications in 2017, whereas the United States contributed a substantially smaller share (5%).

2.2 RTA provisions

We gathered data from the most recent version of the Trade & Environment Database (TREND), which classifies 300 types of environmental provisions across 775 RTAs. [5] We focus on the specific variable from the TREND dataset 10.25: Pesticides, fertilizers, toxic or hazardous products and chemicals, which captures provisions with explicit environmental relevance. To expand our analysis, we also consider the vari-

[3] It is worth noting that other studies have relied on alternative databases to measure domestic environmental regulation (e.g., Martinez-Zarzoso et al., 2023; Avesani et al., 2024). However, in our specific context, the WTO TBT notifications database offers a more suitable source. This is primarily because it allows for precise identification of relevant products through the use of Harmonized System (HS) or International Classification for Standards (ICS) product codes. This level of specificity is essential for accurately capturing regulations targeting fertilizers and pesticides, which is central to our empirical analysis.

[4] These data are drawn from the WTO database downloadable at https://eping.wto.org/en/FactsAndFigures/Notifications. Our sample includes TBT regulating products corresponding to ICS-65, HS-31 and HS-38.

[5] Data and database are available at https://www.chaire-epi.ulaval.ca/en/trend.

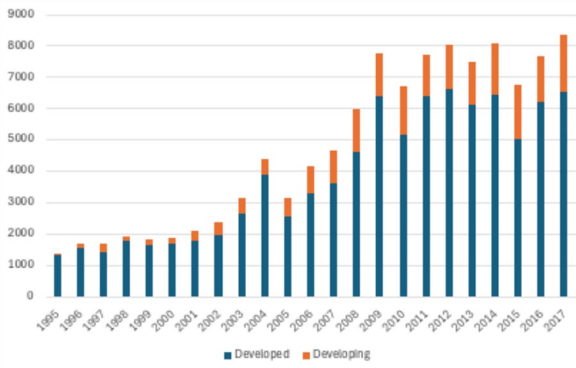

Fig. 1 TBTs on fertilizers and pesticides in force. *Note*: The Figure reports the total number of TBTs concerning fertilizers and pesticides in force (authors' calculations on WTO data)

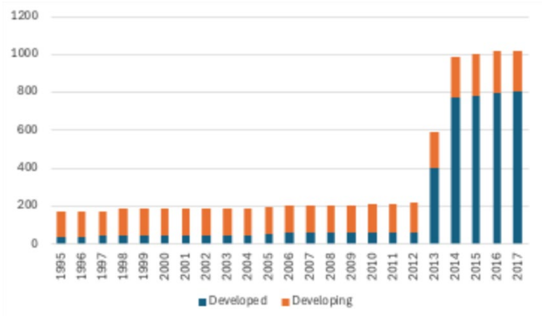

Fig. 2 RTAs provisions on fertilizers and pesticides. *Note*: The Figure reports the total number of RTAs provisions concerning fertilizer and pesticides (authors' calculations on TREND data)

able 10.26: Organic foods, which captures commitments aimed at promoting organic production; this may lead to the introduction of new regulations on the use of fertilizers and pesticides.

According to the TREND database, 79 RTAs include provisions specifically concerning fertilizers and pesticides, and these agreements span a broad geographical range: 32 involve the European Union, 30 involve countries in the Americas, and 27 involve Asian countries. In contrast, only five RTAs involve African countries and three include Oceania. Provisions related to organic foods appear in 16 RTAs, the majority of which also involve the European Union.

Over the past decade, the number of RTAs containing provisions on fertilizers and pesticides has increased, mirroring the broader trend of deepening trade agreements. The language and content of these provisions vary across RTAs but commonly include commitments to ensure compliance with internationally recognized standards; cooperate on the safe handling and marketing of agrochemicals; prohibit the export of agrochemicals banned domestically; promote regulatory harmonization. Provisions on organic foods often include commitments to support organic production and marketing and to adopt relevant standards.

Based on these data, we construct two annual country-level variables: the number of RTAs in force each year that include provisions on (i) fertilizers and pesticides and (ii) organic food. Figures 2 and 3 illustrate the evolution of these variables over time.

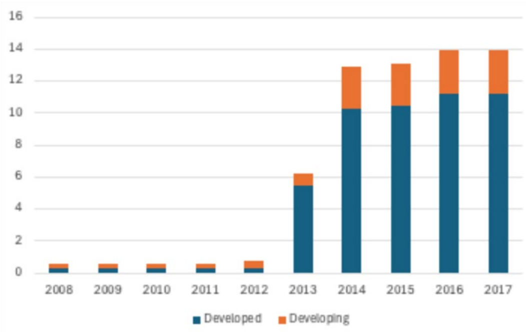

Fig. 3 RTAs provisions on organic food. *Note*: The Figure reports the total number of RTAs provisions concerning organic food (authors' calculations on TREND data)

Notably, provisions have increased significantly since 2013, largely driven by the expansion of the European Union's deep trade agreements. [6]

2.3 Control variables

We include two key time-varying country-level control variables in our empirical analysis. The first variable is tariff. A well-established hypothesis in the literature on non-tariff measures suggests that as tariffs decline, governments may increase the use of non-tariff measures —including TBTs—as alternative tools to protect domestic industries. In this view, TBTs serve as substitutes for tariff protection (Beverelli et al., 2014). Several empirical studies support this hypothesis, particularly for TBTs (e.g., Ghodsi, 2016; Orefice, 2017), although the evidence is more mixed for Sanitary and Phytosanitary (SPS) measures (Boza & Muñoz, 2017; Orefice, 2017). Following this literature, we expect a negative relationship between tariffs and TBTs. We source tariff data from the World Bank's World Integrated Trade Solution (WITS) database and consider average applied tariffs for three product categories: fertilizers, pesticides, and the broader agricultural sector.

The second control variable captures each country's environmental performance in managing fertilizers and pesticides. Stronger environmental performance is often associated with heightened awareness of health and environmental risks, which in turn may motivate the adoption of stricter technical regulations. Limited empirical evidence on the impact of health and environmental concerns on non-tariff measures shows mixed results. While the overall *Environmental Performance Index* (*EPI*) has been found to positively affect TBT (Ghodsi, 2016), public health expenditure appears not to affect Sanitary and Phytosanitary measures (Boza & Munos 2017).

In line with prior research, we use two specific indicators from the EPI project: the Sustainable Nitrogen Management (SNM) Index and the Sustainable Pesticide Use (SPU) Index. [7] We hypothesize that higher values in these indices are associated with a greater likelihood of enacting TBTs.

[6] According to the TREND dataset, in the period 1995–2007 only 4 RTAs were including provisions related to organic food. We hence report in Fig. 3 only the period 2008–2017.

[7] https://epi.yale.edu/.

By including these control variables, we aim to account for two key drivers of TBT adoption: the protectionist motive (captured by tariffs) and concerns over human health and environmental protection (captured by environmental performance).

3 Empirical strategy

The relationship between environmental provisions in RTAs and TBT may be subject to several sources of endogeneity that warrant careful consideration in the empirical analysis. First, unobserved heterogeneity across entities may create omitted variable bias if time-invariant characteristics correlate with explanatory variables, potentially confounding the causal relationship of interest. Second, as aforementioned, reverse causality is an important concern because TBT may influence the propensity of countries to sign RTAs, including environmental provisions. Third, measurement errors in our key variables could attenuate coefficient estimates and introduce classical errors-in-variables bias, particularly given the complexity of coding environmental provisions across diverse trade agreements. Finally, spatial endogeneity could also arise in our specific context, as observations of TBTs may exhibit cross-sectional dependence owing to spatial spillovers, policy diffusion mechanisms, and network effects among trading partners. Our empirical strategy addresses these potential endogeneity issues using a multifaceted approach. [8]

To address endogeneity issues related to possible omitted variables, our benchmark approach employs a static specification with two-way fixed effects (time and individual) to eliminate time-invariant unobserved heterogeneity. This approach effectively controls for country-specific characteristics that may simultaneously affect the adoption of RTAs' environmental provisions and domestic regulations. The time-fixed effects additionally capture global temporal trends in environmental governance that might influence both RTAs and national regulatory frameworks. Our first specification is as follows:

$$envTBT_{i,t} = \alpha_i + \beta_1 envRTA_{i,t} + \sum_{z=1}^{k} \gamma_z x^z_{i,t} + \phi_t + v_{i,t} \tag{1}$$

with $i = 1,\ldots,142$ and $t = 1,\ldots,23$.

$envTBT_{i,t}$ is the count of TBT on fertilizers and pesticides adopted by country i at time t; $envRTA_{i,t}$ is the count of the environmental provisions on fertilizers/pesticides

[8] We preliminary test for the presence in the series of unit roots, and thus integrated processes, that may bias the estimates in terms of time-causality. The tests lead us to reject the null hypothesis of unit root in the panel series and, consequently, to exclude the risk of trend regressions, spurious, due to the presence of time- causality (see Table 6 in the Appendix). Two different testing procedures for panel data have been carried out to test unit root hypotheses: the Levin et al. (2002) test and the cross-sectionally augmented Im, Pesaran and Shin (IPS) test for unit roots in panel models (Im et al., 2003), which is a so-called second-generation panel unit root test because it is robust against cross-sectional dependence.

and/or organic food included in the RTAs; $\sum_{z=1}^{k} \gamma_z x_{i,t}^z$ are country-time variant control variables.

We use an instrumental variable (IV) approach to address endogeneity issues related to reverse causality. To test for reverse causality, we employ the Dumitrescu-Hurlin (2012) panel Granger causality test, which extends the conventional Granger causality framework to heterogeneous panel-data settings. This test allows for parameter heterogeneity across cross-sectional units while examining whether past values of variable X (*env_RTA*) provide statistically significant information about the current values of variable Y ($envTBT$), beyond what is captured by the past values of Y alone. The results, reported in Table 7 in the Appendix, reveal a nuanced causal structure: there is contemporaneous reverse causality (Y causes X), while the causal effect of X on Y operates with a one-period lag. This temporal structure of causality provides important insights into our model specification and justifies the use of lagged explanatory variables as instruments (Bellemare et al., 2017). We instrument potentially endogenous *envRTA* variables using their first lags.

Finally, the implementation of heteroskedasticity-consistent standard errors addresses the potential endogeneity arising from measurement errors in the panel data. This correction is particularly valuable for small panels, as it accounts for heteroskedasticity patterns typical of measurement error bias, thus providing more reliable inferences.

In these static specifications, although the exogeneity and relevance of the instruments are acknowledged, endogeneity problems arise in terms of serial correlation in the residuals (checked through the Godfrey, 1978 and Pesaran, 2015 test procedures). [9] To control for serial correlation, we add a time-lagged dependent variable and estimate a set of dynamic panel specifications using the generalized method of moments (GMM) estimator. This approach addresses potential concerns regarding persistence in both dependent and independent variables, while assessing the dynamic adjustment process in regulatory frameworks and controlling for unobserved heterogeneity through the panel structure. Hence, we estimate the following:

$$envTBT_{i,t} = \alpha_i + \lambda envTBT_{i,t-1} + \beta_1 envRTA_{i,t} + \sum_{z=1}^{k} \gamma_z x_{i,t}^z + v_{i,t} \quad (2)$$

Finally, to capture spatial interactions across units and over time, we use a spatial lag model (Anselin, 2009; Kelejian & Prucha, 1999). To account for spatial endogeneity concerns, we implement spatial econometric techniques that explicitly model cross-sectional dependence using spatial weight matrices based on trade relationships and geographical proximity. This approach allows us to control for potential regulatory spillovers and policy diffusion effects across countries that share trade connections and regional characteristics. A spatial dynamic panel model is the most appropriate for controlling for serial correlations between countries.

[9] The Breusch–Godfrey and Pesaran CD tests led us to reject the null hypothesis of time and cross-sectional independence (see Table 1 in the next section).

The extent of the cross-sectional correlation is measured using a 'spatial matrix' W, which is a non-negative $N \times N$ matrix (where N is the number of countries) of known constants. W describes the spatial arrangement of the units in the sample, and its non-zero element w_{ij} specifies the strength of the relationship between county i and country j. Moreover, w_{ij} indicates whether two locations can be considered as neighbours. The diagonal elements w_{ii} are all set equal to 0 to exclude self-neighbours by convention. Such a weighted spatial matrix is not symmetric and is generally used in row-standardized form.

We hence estimate the following spatial autoregressive (SAR) model:

$$envTBT_{i,t} = \alpha_i + \lambda \sum_{i \neq j} w_{.j,t} envTBT_{j,t} + \beta_1 envRTA_{it} + \sum_{z=1}^{k} \gamma_z x_{i,t}^z + \varphi_t + v_{i,t} \quad (3)$$

The SAR model captures spillover effects such as external effects or cross-country interactions. Country i 's dependent variable depends on that of its neighbours, and these effects are measured by the coefficient λ. In this way, we capture the potential impact that TBT in one country may have on the TBT of other countries. As mentioned in the introduction, the intuition is that governments could prefer to harmonize their domestic regulations with those of their trading partners, aiming to make their own firms more competitive in foreign markets. This voluntary regulatory convergence is likely to be stronger as more countries have bilateral environmental commitments. Hence, in this context, we do not use the classical spatial matrix, rather, we use a "proximity" matrix between countries in terms of *envRTA* relationship. Our matrix has the same structure as a spatial matrix (main diagonal all null and non-diagonal values indicating the proximity between *ij* countries). For each *i*-country, we calculated the average of *env-RTA* with each *j*-country in from 1995 to 2017 timespan. They represent the w_{ij} elements of the W spatial matrix, that is squared (142×142) and row standardized. For example, in our "proximity matrix" the $w_{23,7}$ element of W measures the proximity between Canada and Australia, and it is equal to 0.0213. That is: 2.13% of Canada's *env-RTA* are with Australia. The $w_{23,25}$ element of W measures the *env-RTA* proximity between Canada and Chile, and it is equal to 0.255. That is: 25.55% of Canada's *env-RTA* are with Chile. Our W proximity matrix considers Chile far closer to Canada and, therefore, in model 3, Chile's TBTs will be weighted more than those of Australia in explaining Canadian TBT. With a "classical" spatial matrix, neighbours have all the same weight.

In order to account for both the spatial lag and the dynamic dimension of TBT discussed in the previous sections, we extend our spatial analysis by incorporating the lagged dependent variable and the lagged spatial term into the model (3). This allows us to simultaneously capture the temporal persistence of TBT measures and their spatial interdependence across countries, providing a more comprehensive picture of the diffusion mechanisms at play.

Specifically, we first estimate a dynamic spatial lag model that includes the lagged dependent variable alongside the spatial lag term. The estimated model takes the following form:

$$env_{TBTi,t} = \alpha_i + \delta env_{TBTj,t-1} + \lambda \sum_{i \neq j} w_{.j,t} env_{TBTj,t} + \beta_1 env_{RTAi,t} + \sum_{z=1}^{k} \gamma_z x_{i,t}^z + \varphi_t + v_{i,t} \quad (3a)$$

where δ measures the degree of temporal persistence.

Second, we extend this specification by including the lagged spatial term on the right-hand side. This specification allows us to capture richer spatial interdependencies within the already established dynamic framework.

The estimated model takes the following form:

$$env_{TBTi,t} = \alpha_i + \delta env_{TBTj,t-1} + \lambda \sum_{i \neq j} w_{.j,t} env_{TBTj,t-1} + \beta_1 env_{RTAi,t} + \sum_{z=1}^{k} \gamma_z x_{i,t}^z + \varphi_t + v_{i,t} \quad (3b)$$

4 Results

Table 1 reports the estimation results of Eq. (1).[10] We first run estimations using the sum of provisions on fertilizers and pesticides and on organic food as an aggregate measurement of RTAs' environmental provisions (column 1). Column (2) reports the estimation results when we consider provisions on fertilizers and pesticides (*RTA1025*) and organic food (*RTA1026*) separately. Column (3) reports the results of previous specifications when we include our exogenous variables: average tariffs of pesticides, fertilizers, and agricultural trade (*Tpes*, *Tfer*, *Tagrtrade*) and *EPIscore* which is the sum of the indexes measuring the sustainable management of fertilizers and pesticides.

Our results show that *i)* provisions on pesticides and fertilizers positively affect TBT (on average, each additional *envRTA1025* leads to an introduction of about 2.5 new TBT), while this is not the case for *envRTA1026* which turns out to exert a negative effect; *ii*) tariffs on pesticides positively influence TBTs, whereas those applied to fertilizers do not exert a significant influence. We find a negative and significant sign for the coefficient of the average tariffs on agricultural trade; *iii*) the coefficients of the sustainable management of fertilizer and pesticide variables are positive and significant, thus confirming the previous literature (Ghodsi, 2016) and our own expectations.

Table 2 reports the results of the robust standard error dynamic estimations (Eq. 2). In all specifications, we instrumented our measurement of RTAs' environmental pro-

[10] Variables measuring environmental provisions, potentially endogenous, are instrumented with their lags. The number of optimal lags selected to instrument the endogenous variables and the number of observations (which varies according to the lag length) are reported at the bottom of Tables.

Table 1 Static panel model estimates

	(1)		(2)		(3)	
	Fixed IV		Fixed IV		Fixed IV	
	estimate	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*
envRTA	0.804***	*0.000*				
RTA1025			2.594***	*0.000*	2.49***	*0.000*
RTA1026			− 1.115**	*0.049*	− 1.076*	*0.071*
Tpes					1.139***	*0.009*
Tfert					0.153	*0.822*
Tagrtrade					− 1.398**	*0.015*
EPIscore					0.766**	*0.028*
F statistics (first stage)	96.668***	*0.000*	48.736***	*0.000*	48.996***	*0.000*
Sargan	2.726*	*0.099*	2.639	*0.267*	2.883	*0.236*
Breusch-Godfrey	1173.5***	*0.000*	1170.3***	*0.000*	1125.3***	*0.000*
Pesaran CD test	64.434***	*0.000*	65.139***	*0.000*	54.99***	*0.000*
N	2,982		2,982		2,982	
Instrumental lags	2		2		2	

envRTA is the sum of *RTA1025* and *RTA 1026.* RTAs provisions are instrumented with their lags. All regressions use the within estimator with robust standard errors.*** p < 0.01; ** p < 0.05; * p < 0.1

Table 2 Dynamic panel model estimates

	(4)		(5)		(6)	
	Dynamic		Dynamic		Dynamic	
	estimate	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*
Lag (TBT)	0.424***	*0.000*	0.425***	*0.000*	0.424***	*0.002*
envRTA	0.306***	*0.008*				
RTA1025			1.061**	*0.034*	1.059*	*0.062*
RTA1026			− 0.714	*0.186*	− 0.652	*0.286*
Tpes					0.471	*0.190*
Tfert					− 0.696*	*0.074*
Tagrtrade					0.128	*0.630*
EPIscore					0.239	*0.171*
F statistic (first stage)	1769.84***	*0.000*	1180,00***	*0.000*	521.11***	*0.000*
Sargan test	129.311	*~1*	131.578	*~1*	127.631	*~1*
Autocorrelation test (1)	− 3.188***	*0.001*	− 3.186***	*0.001*	− 3.169***	*0.002*
Autocorrelation test (2)	1.412	*0.163*	1.408	*0.159*	1.389	*0.165*
Pesaran CD test	50.711***	*0.000*	51.798***	*0.000*	46.149***	*0.000*
N	2,982		2,982		2,982	
Instrumental lags	2		2		2	

envRTA is the sum of *RTA1025* and *RTA 1026.* RTAs provisions are instrumented with their lags All regressions use the GMM estimator with robust standard errors.*** p < 0.01; ** p < 0.05; * p < 0.1

visions with their lags. Column (5) shows that the signs and significance of the coefficients of *RTA1025* are confirmed, whereas that of *RTA1026* is never significant. The coefficients of our control variables (column 6) are not significant. [11]

The dynamic model corrects serial correlation (the absence of second-order serial correlation in disturbances is not rejected), but it does not account for cross-sectional correlation. Consequently, given the large cross-sectional dimensions of our panel data set, the GMM estimator may be inconsistent.

The results of the estimations of Eq. 3 are reported in Table 3 (columns 7–9). The positive and significant spatial lag coefficient confirms our hypothesis of spillover effects on the *envTBT* of a generic *i*-country member of the RTAs including provisions on fertilizers, pesticides, and organic food. If one country is a partner of an RTA containing these provisions, then it will tend to align its domestic regulations on fertilizers and pesticides with those of its partners. On average, a country issues one more TBT on fertilizers and pesticides for every three TBT issued by their partners.

The results in Table 3 confirm the signs and significance of the variables *envRTA* and *RTA1025*. On average, for each additional *envRTA* approximatively 1.2 new TBT for fertilizers or pesticides is introduced (column 7), and one more *RTA1025* leads to about 2.5 new TBTs for fertilizers and pesticides (columns 8 and 9). The coefficient of the variable *RTA1026* is confirmed to be not significant. The coefficients of tariffs applied to fertilizers and pesticides are barely significant, while, as shown in Table 1, tariffs on agricultural trade exert a negative impact. The *EPI* index is confirmed to positively affect TBT.

The SAR specification further improves the quality of estimates; the weighted robust standard error estimator corrects the bias effects of serial and cross-correlation between countries. The null hypotheses of the residual dependence across countries (LM test) and between countries (Pesaran CD test) cannot be rejected.

The results of models 3a) and 3b) are reported in Table 3, columns (10) and (11), respectively.

Analyzing these results, important evidence emerges regarding the temporal and spatial dimensions of TBT diffusion. The 3a) specification reveals strong temporal persistence in TBT measures, with a lagged dependent variable coefficient (δ) significant at the 1% level. This indicates that approximately 69% of TBTs from one period carry over to the next. The contemporaneous spatial lag coefficient (λ) remains posi-

[11] To ensure the validity of dynamic identification strategy we assessed instrument exogeneity, through Sargan tests, and we evaluated if the instruments are sufficiently strong for each first stage regression, addressing concerns about potential weak instrument bias. These statistics, reported in Table 2, led us to reject the hypothesis that instruments are not valid and/or week (since F first stage statistics consistently exceed conventional thresholds for instrument strength). Moreover, dynamic panel data models estimated via GMM are susceptible to weak instrument problems. Even when under identification can be avoided, this does not necessarily imply the presence of strong instruments (Windmeijer, 2024). For this reason, we performed the Sanderson—Windmeijer conditional under identification test to assess the strength of the first-stage instruments in the presence of fixed effects and multiple endogenous variables (Sanderson & Windmeijer, 2016). The test statistics provide evidence to reject the null hypothesis that the instruments are weak. The high conditional F-statistics obtained from the Sanderson—Windmeijer tests for each dynamic specification are all above 10, confirming the robustness and validity of the instruments.

Table 3 Spatial dynamic panel model estimates

	(7)		(8)		(9)		(10)		(11)		(12)	
	SAR		SAR		SAR		SAR		SAR		SAR Spatial	
	estimate	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*
Spatial lag (TBT)	0.302***	*0.001*	0.324***	*0.000*	0.395***	*0.000*	0.113***	*0.000*			0.101***	*0.000*
Spatial lag (lag TBT)									0.175***	*0.000*		
Lag (TBT)							0.686***	*0.000*	0.574***	*0.000*		
envRTA	1.217***	*0.000*										
RTA1025			2.578***	*0.000*	2.426***	*0.000*	0.609**	*0.011*	0.437*	*0.067*	2.369***	*0.000*
RTA1026			− 0.171	*0.621*	− 0.298	*0.367*	− 0.182	*0.449*	− 0.098	*0.678*	− 0.21	*0.146*
Tpes					0.448*	*0.099*	0.128	*0.536*	− 0.016	*0.936*	0.443**	*0.028*
Tfert					− 0.062	*0.856*	− 0.050	*0.842*	− 0.100	*0.688*	− 0.089	*0.864*
Tagrtrade					− 1.960***	*0.000*	− 0.73***	*0.000*	− 0.730***	*0.000*	− 2.022***	*0.000*
EPIscore					1.099***	*0.000*	0.440***	*0.000*	0.490***	*0.000*	1.212***	*0.000*
Pesaran CD test	− 1.004	*0.316*	− 1.163	*0.245*	− 0.599	*0.549*	− 0.402	*0.6877*	− 0.469	*0.639*	1.03	*0.303*
LM test	5.932	*0.015*	4.507	*0.034*	2.144	*0.143*	0.817	*0.366*	0.756	*0.385*	10.499	*0.001*
N	3,124		3,124		3,124		3,124		3,124		3,124	
Instrumental lags	1		1		1		1		1		1	

envRTA is the sum of *RTA1025* and *RTA1026*. RTAs provisions are instrumented with their lags. All regressions use the TSLS estimator, with weighted robust standard errors and the matrix based on proximity, with exception of results reported in columns (12), where a spatial matrix has been used, as explained in the text. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

tive and significant, though smaller in magnitude compared to the static specifications. This reduction is expected, as part of the interdependence previously captured by the spatial term is now absorbed by the temporal dynamic component.

The inclusion of the lagged spatial (column 11) term provides a more nuanced understanding of diffusion mechanisms. Both the temporal lag coefficient (δ) and the lagged spatial coefficient (λ) are significant at the 1% level, suggesting a gradual learning and adaptation process to partners' regulations.

In both dynamic specifications, the *RTA1025* coefficient maintains its positive sign and statistical significance, confirming that trade agreements with environmental provisions stimulate TBT adoption even when controlling for temporal and spatial dynamics. The coefficient of the variable *RTA1026* is confirmed to be not significant as the coefficients of tariffs applied to fertilizers. The *EPI* index is confirmed to positively affect TBT.

The diagnostic tests (Pesaran CD test with *p-values* of 0.688 and 0.639 respectively) fail to reject the null hypothesis of no cross-sectional dependence in residuals, indicating that specifications 3a) and 3b) adequately capture both temporal and spatial interdependencies, substantially improving estimate quality compared to static models. These results confirm the importance of jointly considering temporal and spatial dimensions in the diffusion of environmental trade policies, highlighting how regulatory decisions are influenced both by domestic path dependency and by regulatory convergence processes with trading partners.

For the robustness check, we estimate Eq. (3) for the entire sample using a spatial matrix instead of the proximity matrix. The *Wsp* spatial matrix is constructed by applying the simple contiguity method which sets that the generic w_{ij} weight of the matrix is 1 if countries i and j have a common boundary, 0 otherwise. In the spatial case *Wsp* is a non-negative $N \times N$ matrix (where N is the number of countries) of known constants as well. The non-zero element w_{ij} specifies the presence of a common boundary indicating whether two countries can be considered neighbours. The diagonal elements w_{ii} are all set to 0 to exclude self-neighbours by convention. Moreover, it is not symmetric, and it is used in a row-standardized form. The *Wsp* row corresponding to Finland, for example, has only three nonzero weights, corresponding to Norway, Sweden, and Russia, the neighbouring countries. Obviously, the three non-zero weights are all equal to 0.33. The results of this estimation, reported in Column 12, confirm those obtained using a proximity matrix. Endogeneity problems arise in the residuals of the SAR specification with a spatial matrix *(Wsp*). This finding confirms that dealing with endogeneity by considering spillover effects through a spatial lag model is an appropriate approach.

Given that the SAR model proves to be the most appropriate one, we deploy it to examine the potential heterogeneity across groups of countries. The potentially endogenous variables (*envRTA* and *RTA1025*) are instrumented with their lags. [12] We run estimations using the same specification as in Table 3 (column 10) for two

[12] *RTA1026* is not included in these estimations because of the limited number of available observations from developing countries for this variable.

sub-samples of the total panel of 142 countries: developed and developing countries (Table 4). [13] While the temporal lag coefficient (δ) is significant at the 1% level for both groups of countries, our spatial lag variable is confirmed to be positive and significant for developed countries but not for developing countries. Overall, the significance, signs, and magnitudes of the coefficients of *envRTA* and *RTA1025* are similar across the two subsamples. For both groups of countries, the impact of RTA provisions on fertilizers and pesticides is positive, the *EPIscore* has a positive effect, and tariffs on agricultural trade exert a negative impact. Our results show the heterogeneous impact of specific tariffs. Specifically, while tariffs on pesticides do not affect TBT in developing countries, the coefficient for developed countries is positive and significant. Hence, for pesticides, we find (unexpected) evidence of "complementarity," rather than substitution, between TBT and tariffs in developed countries. [14]

5 Conclusions

This paper provides additional empirical evidence on the effectiveness of environmental provisions in RTAs, focusing specifically on fertilizers and pesticides—two of the most critical areas regarding the potential negative environmental externalities of trade liberalization. We assess the impact of these provisions on the strengthening of domestic regulations by analysing TBTs related to fertilizers and pesticides.

Table 4 Countries' Heterogeneities

	(13)		(14)	
	SAR Developing		SAR Developed	
	estimate	*p-value*	*estimate*	*p-value*
Spatial lag(TBT)	0.062	*0.560*	0.056**	*0.021*
Lag (TBT)	0.538***	*0.000*	0.738***	*0.000*
RTA1025	0.625**	*0.035*	0.329***	*0.005*
Tpes	− 0.145	*0.482*	0.208	*0.690*
Tfert	0.143	*0.566*	− 0.684	*0.259*
Tagrtrade	− 0.606***	*0.000*	− 1.149***	*0.000*
EPIscore	0.275*	*0.068*	0.537***	*0.000*
Pesaran CD test	− 0.746	*0.455*	2.113**	*0.034*
LM test	0.319	*0.572*	1.542	*0.214*
N	1,672		1,452	
Instrumental lags	1		1	

RTA1025 is instrumented with its lags. All regressions use the TSLS estimator with weighted robust standard errors.*** : p < 0.01; **: p < 0.05; *: p < 0.1

[13] The first sample includes 76 developing countries and the other 66 developed countries. Following the World Bank classification distinguishing the economies in four income groups, 'developed' countries are those included in high and upper-middle income groups, while 'developing' countries are in the low and lower-middle income groups.

[14] We also check whether our findings are driven by the EU countries, by adding the EU dummy in our estimations. As shown by Table A4 in the Appendix, the main findings are confirmed.

Our panel dataset integrates data on TBTs notifications concerning fertilizers and pesticides with information on RTAs environmental provisions that specifically address these products. A key innovation of this study lies in its consideration of potential spillover effects, whereby TBTs enacted in one country may influence the adoption of similar measures in other countries. Given the unobservable nature of these interactions, we adopt a spatial econometric model based on a trade proximity matrix, which represents the most appropriate empirical strategy among the various models estimated.

Our findings are robust across multiple model specifications, estimators, and alternative assumptions. First, we find that RTA provisions specifically related to fertilizers and pesticides significantly increase the number of TBT notifications concerning these products, both in developed and developing countries. These results are consistent with the hypothesis that economic, political, and institutional mechanisms driving regulatory stringency are at work when countries enter into deep RTAs. While we acknowledge that an increase in environmental regulations does not automatically translate into improved environmental outcomes, the effectiveness of environmental provisions in RTAs depends, as a first step, on their translation into domestic regulatory frameworks. From this perspective, our results confirm and extend the findings of previous studies (Abman et al., 2024; Bayramoglu et al., 2023; Gozlan & Lochard, 2024), suggesting that greening RTAs by including targeted commitments can contribute to mitigating the negative environmental externalities associated with trade liberalization through enhanced domestic regulation.

Secondly, we find that RTA provisions concerning organic food do not have a significant effect on TBTs related to fertilizers and pesticides. In this case, international commitments do not appear to translate into more stringent domestic regulations. The limited effectiveness of these provisions in prompting regulatory changes may be attributable to the prevalence of alternative policy actions taken to fulfil these RTAs commitments, rather than the adoption of new standards on fertilizers and pesticides.

Third, our analysis does not support the hypothesis of a substitution effect between TBTs and tariffs in the case of fertilizers and pesticides. In particular, we find that tariffs on pesticides in developed countries exert a positive effect on TBTs, challenging the commonly held assumption of a general substitution between tariff and non-tariff measures. Conversely, the average level of tariffs across the broader agricultural sector is negatively associated with TBTs on fertilizers and pesticides, in line with previous findings on overall trade protection (Orefice, 2017; Ghodsi, 2016).

Fourth, we find strong evidence that countries with higher environmental performance in managing fertilizers and pesticides are more likely to adopt TBTs related to these products. This result reinforces previous findings (Ghodsi, 2016) and supports the notion that environmental concerns represent a key driver behind the enactment of TBTs.

Fifth, the hypothesis that TBT in one country can influence TBT in other countries is confirmed by the results, but this effect is statistically significant only among developed countries. This finding suggests the presence of voluntary regulatory convergence, which becomes more pronounced when a greater number of developed countries are engaged in bilateral environmental commitments.

The findings of this study provide the first empirical evidence of the effectiveness of environmental provisions in RTAs in strengthening domestic regulations governing the use of agrochemicals. This contributes to a growing body of research exploring the intersection of trade policy and environmental governance. The empirical analysis in this area, however, can be further improved and expanded in several directions.

First, improvements in the quality and granularity of available datasets could enhance the robustness of empirical assessments by allowing for the inclusion of a larger number of, and more refined, metrics - particularly those related to RTAs environmental provisions concerning agrochemical-specific products. Second, future research could explore the impact of domestic regulatory stringency on the likelihood of entering RTAs that include environmental provisions. To the best of our knowledge, this direction of causality remains underexplored in the existing literature. Third, our spatial model estimations confirm that TBTs enacted in one country can influence TBTs in countries with high levels of trade proximity; however, this effect is observed only among developed countries. Further research is warranted to examine the underlying factors driving this heterogeneity in spillover effects.

The results also carry important policy implications. “Greening” RTAs by incorporating specific environmental provisions appears particularly relevant for developing countries as a means to mitigate the negative environmental externalities associated with trade liberalization. Notably, our findings indicate that while environmental provisions in RTAs are effective in promoting domestic regulatory action on fertilizers and pesticides, no spillover effects from TBTs are observed for developing countries. This suggests that for these countries, RTA commitments themselves—rather than indirect influence from trading partners—are a key mechanism driving regulatory change.

Appendix

See Tables 5, 6, 7 and 8.

Table 5 Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Full Sample					
RTA1025	3,381	2.42	6.21	0	32
RTA1026	3,381	1.28	5.13	0	39
envTBT	3,381	32.78	61.87	0	583
Tpes	2,471	4.59	5.11	0	52.06
Tfert	2,474	2.25	3.62	0	35.59
Tagrtrade	2,484	8.86	8.41	0	73.69
EPI score	2,484	41.14	17.64	0	98.91
Developed Countries Subsample					
RTA1025	1,538	2.92	7.52	0	32
Tpes	1,241	3.07	3.26	0	30.37
Tfert	1,235	1.76	2.41	0	19.73
Tagrtrade	1,242	5.69	7.37	0	48.37
EPI score	1,242	44.95	20.53	0	98.91
Developing Countries Subsample					
RTA1025	1,768	2.04	4.90	0	29
Tpes	1,230	6.12	6.08	0	52.06
Tfert	1,239	2.73	4.46	0	35.59
Tagrtrade	1,242	12.04	8.18	0	73.69
EPI score	1,242	37.33	13.11	5.45	80.99

Table 6 Unit root tests

*alternative hypothesis: Stationarity

	Levin-Lin-Chu Unit-Root Test*		Pesaran's CIPS Unit roots Tests*	
Variable	estimate	*p-value*	estimate	*p-value*
envTBT	− 4.131	<0.001	− 2.423	<0.001
envRTA	− 21.736	<0.001	− 4.597	<0.001

Table 7 Panel Causality test

Causality direction	Test statistic	p-value
TBT->RTA1025	4.900	0.000
TBT->RTA1026	4.846	0.000
RTA1025 ->TBT	0.440	0.656
First lag of RTA1025 ->TBT	2.809	0.005
RTA1026->TBT	− 1.085	0.278
First lag of RTA1026->TBT	− 1.998	0.046

Table 8 Spatial dynamic panel estimates with EU Member States

	SAR		SAR		SAR		SAR		SAR	
	estimate	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*	*estimate*	*p-value*
Spatial lag (TBT)	0.555***	*0.000*	0.553***	*0.000*	0.467***	*0.000*	0.154***	*0.000*		
Spatial lag (lag TBT)									0.043	*0.147*
Lag (TBT)							0.599***	*0.000*	0.587***	*0.000*
envRTA	0.597***	*0.000*								
RTA1025			1.624***	*0.000*	1.625***	*0.000*	0.448*	*0.053*	0.355	*0.125*
RTA1026			− 0.429	*0.161*	− 0.378	*0.205*	− 0.200	*0.388*	− 0.071	*0.757*
Tpes					0.084	*0.731*	− 0.051	*0.800*	− 0.167	*0.403*
Tfert					− 0.603*	*0.051*	− 0.325	*0.180*	− 0.396	*0.103*
Tagrtrade					− 0.50**	*0.008*	− 0.167	*0.266*	− 0.222	*0.139*
EPIscore					0.594***	*0.000*	0.293***	*0.002*	0.339***	*0.000*
Eu member	127.9***	*0.000*	127.4***	*0.000*	121.1***	*0.000*	58.96***	*0.000*	56.20***	*0.000*
Pesaran CD test	− 0.858	*0.391*	− 0.879	*0.379*	− 0.21	*0.833*	0.472	*0.637*	0.391	*0.697*
LM test	0.353	*0.552*	0.516	*0.472*	3.314	*0.069**	0.274	*0.601*	0.254	*0.614*
N	3,124		3,124		3,124		3,124		3,124	
Instrumental lags	1		1		1		1		1	

envRTA is the sum of *RTA1025* and *RTA1026*. RTAs provisions are instrumented with their lags. All regressions use the TSLS estimator with weighted robust standard errors.*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Decalartions

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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