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ORIGINAL PAPER

Trade agreements and international technology transfer

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Abstract

This is the first paper that analyzes for a global sample of countries how trade agreements that include technology-related provisions impact exports of goods, and how this impact differs depending on the technology content of the goods. It includes estimations of a structural gravity model for a panel of 176 countries over the period 1995–2015. The model differentiates between provisions relating technology transfer, technical cooperation, research and development, and patents and intellectual property rights. It also estimates the differences in these effects depending on whether the trade flow in question is between countries with similar or different levels of development. The main results indicate that regional trade agreements (RTAs) that contain technology provisions generate a significantly higher volume of trade than RTAs that do not, after controlling for the depth of the RTAs. For countries that ratify RTAs that include such provisions, it is exports of technology-intensive goods that increase the most. Trade agreements including such provisions have a heterogeneous effect that varies by income level of the trading partners and depends on the extent to which the RTA incorporates other provisions.

Keywords Trade agreements · Technology provisions · Gravity model · Intellectual propoerty rights · Technology-intensive goods · RTA

JEL codes F13 · F15 · O33

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1 Introduction

Since the 1990s, the defining feature of international economic relations has been the proliferation of trade agreements, which have filled what Bhagwati (1995) described as the "spaghetti bowl" to the brim. These agreements have become more complex over time and have gone from focusing solely on tariff reductions—shallow agreements—to having a much wider scope—deep agreements—in which technology transfer provisions have gone from being the exception to the rule. These provisions, which are among the most controversial elements of regional trade agreements (RTAs)[1] are more far-reaching than the minimum standards of protection provided by the multilateral agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs). They mainly seek to facilitate technology transfer and provide a common regulatory framework to inventors in the areas covered by the agreement. Moreover, strengthening intellectual property rights (IPR) is sometimes established as a prerequisite for developing countries to participate in RTAs with more advanced economies, in order to avoid opposition from interest groups in the latter. For instance, although the European Union (EU) successfully concluded RTAs with Japan and Singapore in 2019 and with Vietnam in 2020, negotiations with India, which started in 2007, were brought to a de facto standstill in 2013. Some critical issues in the negotiation are generic medicine production in India, the existence of technological transfer restrictions and the EU interest in patent protection.

Although these provisions are generally expected to facilitate technology transfer and benefit economic development, the theoretical predictions are mixed. On the one hand, the inclusion of technology provisions in RTAs—especially relating to IPR—should prevent imitative competition in the integrated area and lead to an increase in exports with high technology content (Lai et al., 2020; Maskus, 2016). Moreover, preventing imitation in the South will reduce the production of imitative products, providing an additional boost to Northern exports (Maskus & Penubarti, 1995). Stricter enforcement of IPR could also bring about a shift away from imitation towards licensing (market-based technology acquisition), in turn leading to productivity gains and increased exports (Ivus, 2010; Lai et al., 2020). However, Maskus and Penubarti (1995) discuss a potential market-power effect from stricter IPR, which implies restricted sales and higher prices in the destination markets and hence reduces trade. In the medium term though, stronger protections could also foster innovation in less advanced economies. Finally, more recent models that account for heterogeneous firms find that stronger IPR lower the productivity cut-off of exporting and licensing and hence increase exports (Lai et al., 2020).

Given the abovementioned theoretical predictions, the extent to which the type of innovation and technology transfer provisions included in the RTA could affect trade flows remains an empirical question. The related empirical literature has mostly

[1] We use the WTO definition of RTAs: "RTAs, which are reciprocal preferential trade agreements between two or more partners, constitute one of the exemptions and are authorized under the WTO, subject to a set of rules". https://www.wto.org/english/tratop_e/region_e/region_e.htm.

focused on the trade effects of IPR-related provisions in RTAs (Campi & Dueñas,[2] 2019; Chelala and Martínez-Zarzoso, 2017; Dhingra et al., 2018; Maskus and Ridley, 2019), disregarding the fact that the provisions also include technology transfer cooperation, technical assistance and joint R&D projects. Moreover, these papers cover a limited number of RTAs.

We seek to extend the existing empirical literature in three directions. First, we evaluate the extent to which different technology clauses in RTAs affect trade flows for a global sample of countries. Second, we investigate the kind of goods these clauses affect the most, distinguishing between goods classified according to their technological content. Finally, we examine whether the effects vary by type of clause and income per capita of the signatory countries.[3] According to the theory, we expect the effect to be heterogeneous across goods, to be stronger for goods that are technology intensive, and to depend on the level of development of the trading countries. To achieve these aims, we compiled a database of RTAs with technology transfer and innovation-related provisions, drawing on a detailed analysis of the fine print of trade agreements that have entered into force in the last decades. We classified provisions into four subgroups: (1) General intention to transfer technology, e.g. the RTA between the EU and the Caribbean Community (EU-CARIFORUM) establishes the intensification of activities to promote innovation and technology transfer between the parties; (2) Technical cooperation, e.g. the Japan-Indonesia RTA establishes explicit technical cooperation in the telecommunications sector; (3) Intellectual property, e.g. the South Korea-United States agreement includes the protection of IPR; and (4) Joint work on R&D, e.g. the Chile-Australia RTA regulates trade in R&D and innovation. The provisions mostly refer to all goods, but also contain specific references to given categories such as pharmaceutical and agricultural chemical products.[4] Using these data in combination with bilateral trade flows and a number of control variables, the effect of these provisions on trade are evaluated distinguishing between RTAs with and without technology provisions and controlling for the depth of the RTA. Methodologically, we estimated a gravity model using bilateral exports among 176 countries over the period from 1995 to 2015 to examine whether RTAs impact trade differently depending on which technology-related provisions they include. Our estimations distinguished between the four possible types of clauses.[5]

The main novelties of our study are threefold. First, we extend the types of provisions analyzed to include technical cooperation, innovation, and technology transfer,

[2] The authors estimate a traditional gravity model that disregards multilateral resistance factors, the exclusion of which is known to generate biases in the estimated coefficients of the RTA dummies (Baier & Bergstrand, 2007).

[3] For this purpose, we chose the UNCTAD classification of goods that differentiates between high, medium and low technological content. In relation to countries, we use the United Nations definition, which for 2017 lists developed (North) and developing countries (South).

[4] Some provisions on technology transfer address the interests of strategic sectors, such as laboratories in the case of patents or intellectual property, or industrial sectors supported by the government and for which cooperation in technological matters is included.

[5] In all of these cases, the effects do not derive exclusively from trade between the signatory countries, but also from the specific cooperation instruments that are used as vehicles for RTAs.

in addition to IPR. The second novelty is a methodological improvement, since we estimate a structural gravity model with multilateral resistance terms using the latest techniques put forward in the international trade literature (Head & Mayer, 2014; Yotov et al., 2016; Zylkin, 2017). Finally, we are able to isolate the effect of the technology-type provisions by controlling for the depth of the RTAs, the participation of the signatory countries in the TRIPs agreement,[6] and membership of the World Trade Organization (WTO) and currency unions. If any of these factors were excluded from the model, it could generate biases in the estimation of the main effect.

Our main results show that RTAs that include technology transfer provisions generate a significantly higher volume of trade, which in some cases goes beyond the increase generated by RTAs without these provisions. If we break the results down by sector, for countries that ratify RTAs with technology provisions rather than ones without, it is the exports of technology-intensive goods that increase the most. Broken down by levels of economic development, the effects are found to be heterogeneous and also depend on the number of provisions included in the RTA.[7]

This article is organized as follows. Section 2 reviews the literature on trade, trade agreements and technology transfer. The different types of technology provisions in RTAs and some stylized facts are described in Sect. 3. The specification of the gravity model and estimation methodology are detailed in Sect. 4. Section 5 outlines the results by type of good, type of technology transfer clause, and by the level of development of the trade partners and presents a number of robustness checks, including replications of some results obtained by Campi and Dueñas (2019) and Dhingra et al. (2018). Finally, Sect. 6 outlines our conclusions.

2 Trade, trade agreements and technology transfer

Trade agreements can generate technological spillovers indirectly, through an increase in trade flows, and directly, by including technology related provisions.[8] Although this paper mainly focuses on the second channel, for completeness we briefly discuss the indirect channel.

[6] The TRIPs agreement is the most comprehensive multilateral agreement on intellectual property. It came into effect in 1995.

[7] Another possibility would be to distinguish between the sectoral impact on agricultural trade, industrial trade or even trade in services; we leave this extension for further research. The North–South division allows us to analyze the impact of the treaties when they are signed by countries with the same or different levels of development, considering 'North' as developed countries and 'South' as developing countries, following the UN distinction as we see later in the paper.

[8] The mechanism is direct when these provisions entail cooperation, technical assistance, regulatory changes or enforcement mechanisms. For example, the EU-CARIFORUM agreement covers support for the promotion of innovation, diversification, modernization, development and product and process quality in businesses and in the intensification of activities promoting those links. It also provides enforcement mechanisms concerning intellectual property rights, including corrective measures and penalties in case of infringement.

An excellent summary of the literature on indirect spillovers can be found in Hoppe (2005), who identifies three main factors that determine technology transfer: direct efforts to make the transfer successful, the capacity to adopt new technologies, and the differences between the trading countries. The author concludes that trade enables technology transfer mainly through imports of capital goods and openness to export markets, which enable learning-by-doing, thus increasing total factor productivity (TFP). Along the same lines, Keller (2004) shows evidence indicating that imports are a significant channel for technology diffusion. For instance, bilateral relations may provide information on technologies developed abroad, when the importer receives and analyzes the good. Alternatively, migration flows could also provide such information. People with different technological backgrounds may travel to the destination country carrying their different knowledge, which they transfer to the local population in the importing country.[9] Similarly, Madsen (2007) draws on 135 years of data on TFP and imports with high-technology content for OECD countries and finds a robust relationship between TFP and knowledge imports. Specifically, technological knowledge spillovers contributed to TFP-related convergence among OECD countries between 1870 and 2004. These indirect spillover effects may arise with or without RTAs. For instance, they can be a consequence of unilateral trade liberalization policies. Conversely, direct transfers of technology require explicit commitments. RTAs can be used as a tool to increase technology transfer not just through trade itself but also through specific provisions that regulate this transfer and cover aspects related to technical cooperation. Ivus (2010) points to the existence of a virtuous circle by showing that better consolidated property rights have positive effects on trade. In particular, the author finds that the increase in IPR in response to the TRIPs agreement fostered patent-sensitive exports from developed to developing countries.

Since most RTAs with technology provisions specifically state that members have to comply with TRIPs, it is important to refer here to the main purpose of this agreement. TRIPs is a minimum standards multilateral agreement concerning intellectual property that provides protection for nearly all forms of IPR in WTO member countries. Those countries are free to determine the appropriate method of implementing the provisions of the agreement in accordance with their own legal system. TRIPs also includes enforcement, remedies and dispute resolution procedures. Although the idea is that all WTO members will have to comply with TRIPs, specific transition periods were originally established giving developing countries more time—initially until 2005—to adapt their legal system to certain obligations and to comply with them. The waiver was extended up to 2013 for the least developed countries and until 2016 for certain obligations, mostly concerning pharmaceutical products. Detailed information can be found on the WTO website.

Several authors have investigated the effect of TRIPs on trade and found a significant increase in imports of high-technology products after ratifying the agreement

[9] An additional technology transfer mechanism may be mergers or acquisitions with foreign FDI, where new technologies spill over into the host sector. In fact, the exchange of goods, services or ideas (people) can lead to technology transfer, even through informal channels, or through educational exchange programs. In this paper we only study one specific mechanism.

(Ivus, 2010; Delgado et al., 2013; Maskus and Yang, 2018). The main difference between TRIPs and the technology provisions included in the RTAs is that the latter are a means to reinforce the compliance mechanisms and concretize the technical cooperation procedures already established in TRIPs; they also serve as a bridge to ensure enforcement of the national regulations.

Intellectual property has been analyzed by Campi and Dueñas (2019), who explore how RTAs with IPR chapters affected trade for a panel of 110 countries over 19 years. The authors distinguish between products that are highly intellectual property-intensive and those that are not, finding that the results are similar for both types of goods. Surprisingly, the authors find that trade flows between developed countries benefit most, but do not observe substantial gains for developing countries. However, they estimate a gravity model that does not incorporate the so-called time-variant multilateral resistance terms and excludes zero trade flows from the analysis. Generally speaking, these two factors generate biases in the RTA effects (Head & Mayer, 2014).

Maskus and Ridley (2019) also focus on IPR-related RTAs and their effect on the composition on trade. The authors adopt an impact evaluation approach defining treatment RTAs as those in which one partner is the US, the EU or the EFTA. They find that although the effect on total trade is limited, there is a sizable effect on IPR-sensitive sectors.

Finally, Dhingra et al. (2018) examine the contribution of deep non-tariff provisions on international trade in goods and services. When considering IPR provisions separately, they do not find that RTAs with these provisions boost gross bilateral trade in goods. This could be due to the fact that many of the trade agreements in force are not covered by their limited sample of 43 countries.

We contribute to the cited literature by using a global sample of countries, applying an enhanced econometric methodology and considering a finer classification of technology-related provisions than in previous studies.

3 Trade agreements containing technology provisions

To carry out this study, we created a database that drew on a detailed analysis of the fine print of trade agreements. The process started by screening information from the legal text of 302 bilateral or multilateral trade agreements filed with the WTO, the World Bank, or the Organization of American States (OAS). From these agreements we selected those coded as free trade agreements (FTAs), economic integration agreements (EIAs), FTAs & EIAs and Custom Unions (CUs), thus excluding Partial Scope Agreements (PSAs) and Preferential Trade Agreements (PTAs).[10] The remaining agreements in our dataset total 231, of which 205 were signed between 1995 and 2015, which is the period covered in our empirical analysis. We categorized agreements depending on whether they contained provisions on general

[10] In a previous version, we included Partial Scope Agreements (PSA) and Economic Cooperation Agreements (ECA) examining a total of 302 agreements. We have eliminated them from this section since the empirical analysis only considers RTAs that are at least FTAs.

intention to transfer technology; technical cooperation; R&D and innovation; and patents and intellectual property.[11]

More specifically, the first category "general intention to transfer technology" refers to RTAs that include innovation policies, participation in framework programs on innovation, the promotion of technology transfer and dissemination of new technologies. The second category "technical cooperation" lists shared research projects, exchange of researchers, and development of public–private partnerships as objectives of the RTAs. In the third group "R&D and innovation" the text of the RTAs refers to collaboration in research and development projects and innovation. Finally, the fourth group "patents and intellectual property rights" contain RTAs with provisions that refer to patenting activities and intellectual property in the corresponding regulatory framework, obligations and enforcement mechanisms. We believe that the categories allow us to better distinguish between general intentions, specific forms of cooperation, commitments and obligations, which is important for the empirical analysis.

The technology-related provisions included in deep RTAs mostly refer to all goods, but also contain specific references to certain sectors. For example, Chapter 2 of the RTA between the EU and CARICOM is dedicated to Innovation and IPR. Section 1 contains six articles, of which two refer to specific sectors, namely, information and telecommunication technologies and renewable energy. In Sect. 2, most articles refer to all sectors, with special references to plant varieties and animals. It contains four subsections dedicated to listing the main principals, defining standards and covering enforcement and cooperation matters. According to subsection 1, the signatory countries have a transition period in which to enact the corresponding national laws required to comply with the given obligations; this period is 6 years in general and 12 years for least developed countries. Moreover, special references to compliance with international agreements, such as TRIPs and WIPO, are included. The wording used is "*signatory countries shall comply with…*". Subsection 4 gives a very detailed description of the procedures concerning infringement of the obligations, remedies and corrective measures to be applied. A second example is the agreement between the US and South Korea, which dedicates 12 articles in Chapter 18 to IPR. Article 18.11 states the obligation to ratify and comply with the 10 international agreements listed. These include conventions, such as Paris and Berne, and treaties, such as Budapest and Singapore. Only one article (18.9) refers to "*certain regulated products*", specifically to pharmaceutical and agricultural chemical products.

The sum of the four categories is greater than the number of agreements because there are agreements that include more than one of the types of technology provision considered here. All the same, our analysis reveals that from1995 to 2015 most agreements contain at least one type of technology provision. In particular, 152

[11] We consider the full set of free trade agreements that have been notified to the WTO up to December 2016, in keeping with the methodology proposed by Hofmann et al. (2018). The authors classified trade agreements based on the provisions they include on different aspects such as environment, labor, social and intellectual property rights issues. In the empirical analysis we restrict the sample to those RTAs signed after 1994, since trade data from UNCTAD disaggregated by technological content are only available from 1995 onwards.

RTAs contain at a minimum one type, whereas 31 include all four types analyzed and 53 have none.

Among the agreements that include all four areas, the main proponents are the EU (with Caribbean, North African and Eastern European countries, Central America, Chile, Israel and South Africa) and EFTA (with Colombia and Peru), Costa Rica (with China and Singapore), the United States (with Panama and Peru) and Chile (with Turkey), some of which are geographically close to the other party (for example the US-Panama agreement) and some of which are not (Costa Rica-Singapore).

Among the agreements that do not include any of these clause types, many are between developing countries, with fewer between developed and developing countries (5 promoted by the EU, 7 by EFTA, 2 by the US).

The distribution of exports depending on the type of provision included is shown in Fig. 1. The graph indicates that the density curve for export flows within RTAs with provisions in patents and IPR is located to the far right of the graph. Slightly to the left is the plot for those with provisions tackling technology cooperation, as well as the one for RTAs with technology transfer provisions, and a bit more to the left the plot for RTAs with R&D cooperation clauses. In comparison, trade within RTAs with no provisions referring to any technology topic shows a distribution denser towards the left side of the graph and with a significantly lower density at the average.

In order to compare the distribution of trade within and outside RTAs, Fig. 2 shows a comparison of density estimates for export flows between pair of countries with no RTAs and those with RTAs with and without technology provisions. The density curves reveal that the distribution of exports is further to the right and with a higher concentration of points around the average for countries with RTAs with such provisions, whereas it is more disperse and shows a lower average for trade within RTAs without tech-provisions. In comparison, the distribution of exports outside RTAs is located more to the left of the picture. Similar outcomes are obtained when Kernel density estimates are shown for high-, medium- and low-technology-content export flows (see Figs. 3, 4, 5 in the Appendix).

Given that Figs. 1 and 2 show unconditional differences in exports, we move in the next section to present the empirical strategy that will allow us to identify causal effects.

4 Empirical strategy

In this section we first outline the main hypotheses and then present the model specification (4.1) and data description (4.2). The stylized facts described in Sects. 2 and 3 indicate that the technology provisions found in the RTAs mostly refer to all goods traded, but also contain specific references to certain categories. This is particularly

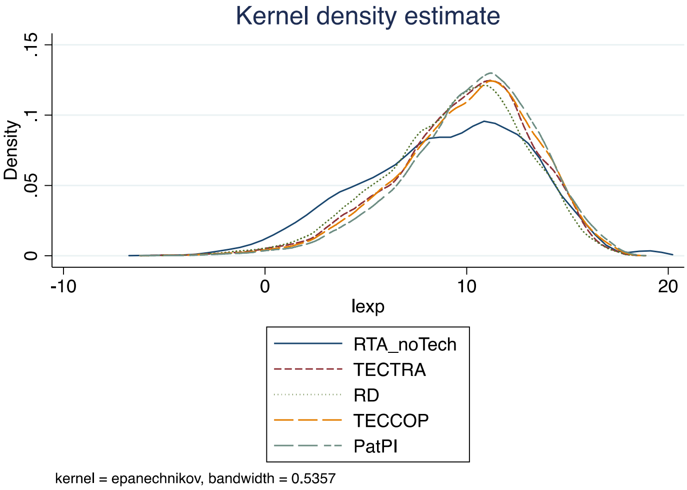

Fig. 1 Distribution of aggregated exports by type of provision. *Source*: Compiled by the authors based on bilateral and multilateral trade agreements

so for the pharmaceutical and chemical sectors, renewable energies and plant varieties and animals. Therefore, we start with an analysis at aggregate level and proceed with a separate analysis for specific sectors. We distinguish between high-, medium- and low-technology-content goods.

The main hypotheses are: (1) Shallow RTAs have a positive effect on trade in goods due to the elimination of tariffs among the member countries,[12] whereas deep agreements have a greater trade effect. (2) With the inclusion of technology-related provisions, which stimulate technology transfer and protect innovations, a direct technology-related effect on trade is generated, in addition to the expected positive effect postulated in (1). (3) The direct and indirect effects could vary depending on the type of goods traded and the level of development of the trading partners. (4) The effects could vary by provision.

4.1 Specifications for the gravity model

The gravity model has been widely used to predict bilateral trade flows between countries as it is nowadays considered to be a structural model with solid theoretical underpinnings (Allen et al., 2014; Anderson, 1979; Anderson & Van Wincoop, 2003; Bergstrand, 1985; Eaton & Kortum, 2002; Feenstra, 2016). It is particularly appropriate for estimating the effects of trade policies and the importance of the costs of trade that are associated with distance and trade facilitation factors.

[12] Shallow integration involves the elimination of barriers to the movement of goods and services across national borders within the RTA, whereas deep integration involves establishing or expanding the institutional enviornment in order to facilitate trade.

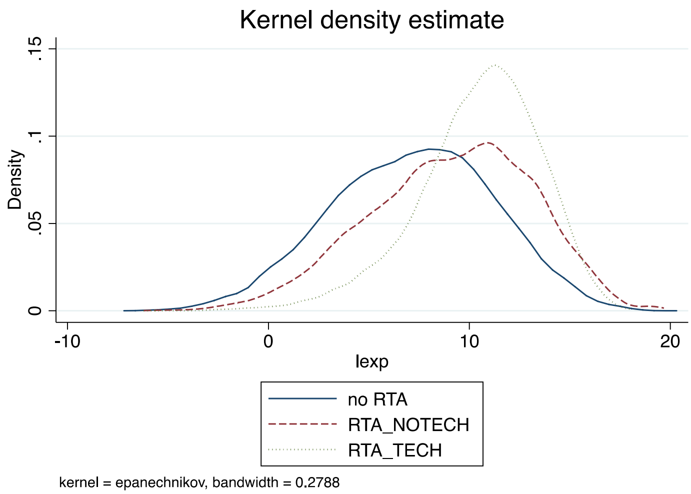

Fig. 2 Distribution of aggregated exports by type of agreement. *Source*: Compiled by the authors based on RTAs and exports (UNCTAD). Lexp is ln of total exports. Years 1995 to 2017

Our estimations will capture the effects on bilateral trade of RTAs without and with technology provisions. When an RTA does not contain such provisions, the effect on trade will be solely due to the elimination of trade barriers. RTAs with provisions will have an extra "direct" effect on trade due to the increasing collaboration in R&D and the protection of IPR, particularly in technology-intensive sectors. The econometric model captures the differences between RTAs with and without technology provisions controlling for the number of other provisions that are not trade-related. In other words, we compare agreements of similar depth and in this way the try to mimic the counterfactual, that is, similar RTAs without those provisions.

Two of the model's most widely appreciated properties are its structural flexibility, which can accommodate the different factors that affect trade, and its predictive power for aggregate trade flows. In its simplest form, when applied to trade, the gravity model predicts that the bilateral exports between two countries are directly proportional to the product of their economic "mass" and inversely proportional to the costs of trade (distance) between them.

According to the underlying theory that has been reformulated and extended by Anderson and van Wincoop (2003), the model assumes constant elasticity of substitution and product differentiation by place of origin. In addition, prices differ among locations due to symmetric bilateral trade costs. The reduced form of the model is specified as

$$X_{ijt} = \frac{Y_{it}Y_{jt}}{Y_t^W}\left(\frac{t_{ijt}}{P_{it}P_{jt}}\right)^{1-\sigma} \tag{1}$$

where X_{ijt} is bilateral exports from country i to country j in year t, and Y_{it}, Y_{jt} and Y_t^W are the gross domestic products in, respectively the exporting country, the importing country and the world in year t. t_{ijt} denotes trade costs between the exporter and the importer in year t and P_{it} and P_{jt} are the so-called multilateral resistance terms (MRT).[13] σ is the elasticity of substitution between all goods.

The log-linearized specification of the gravity model is as follows:

$$lnX_{ijt} = \delta_t + \alpha_1 \ln Y_{it} + \alpha_2 \ln Y_{jt} + (1-\sigma)lnt_{ijt} - (1-\sigma)lnP_{it} - (1-\sigma)lnP_{jt} + \varepsilon_{ijt} \tag{2}$$

where t represents annual periods; X_{ijt} are the exports from country i to country j in period t in current US dollars. Y_{it} (Y_{jt}) indicates the exporter's (importer's) GDP, all of which are expressed in natural logarithms (ln) and the constant (δ_t) represents world income that varies over time. The trade cost between the trading partners is usually proxied with time-invariant and time-variant factors that facilitate or hamper trade. Among the former are the geographic distance between countries i and j and other bilateral dummy variables that take the value of 1 if countries i and j share a language, have a shared border, or have colonial ties.[14] Among the latter are: being a member of a trade agreement (RTA), currency union (CU), the WTO or having ratified TRIPs. Finally, $\varepsilon_{\mathrm{ijt}}$ is the error term and is assumed to be identically and independently distributed.

Estimating the coefficient for the *RTA* variable will allow us to evaluate the change in bilateral exports using information from before and after the entry into force of each agreement, indicating whether or not exports between each pair of RTA member countries have increased significantly as a consequence of access to the integration area. In the following estimations, we also distinguish between RTAs depending on whether they include any of the four types of technology transfer clause described above.

In line with the recent gravity literature, the MRT are modeled as time-varying country-specific dummies, as specified in Eq. (3) below. And to overcome the potential endogeneity of the RTA variable we follow Baier and Bergstrand (2007) and introduce bilateral time-invariant dummy variables to account for all unobserved heterogeneity that is attached to each country pair relationship.

[13] Multilateral resistance terms reflect relative trade costs with respect to the rest of the world. This concept was introduced by Anderson and van Wincoop (2003) into the gravity model. Bilateral trade is not only affected by bilateral interactions, but also by interactions with the rest of the world.

[14] Other geographical factors that vary by country, such as the geographic area (*Area*) of countries i and j and dummy variables that indicate whether they have access to the sea (*Landlock*) have also been used in the traditional gravity literature.

$$lnX_{ijt} = \delta_{ij} + \tau_{it} + \varphi_{jt} + \gamma TP_{ijt} + \sum_k \beta_k RTA_{kijt} + \varepsilon_{ijt} \quad (3)$$

where the *RTA* variable denotes both countries (country pair *ij*) being members of trade agreements in period *t*, and *k* indicates whether the agreement contains provisions on innovation and technology transfer (RTA_tech, k = 1) or does not (RTA_notech, k = 2). We also consider the depth of the agreement (RTA_depth, k = 3). RTA_depth indicates the depth of the agreement, where depth is defined on the basis of the number of provisions covered and is taken from Dür et al. (2014).[15] TP_{ijt} represents other time-variant trade cost variables, as described below Eq. (2), namely, CU, WTO and TRIPs. The fixed (bilateral) effects associated with trade, δ_{ij}, represent the time-invariant characteristics of the trade relationship between *i* and *j* and are included to avoid biases due to unobservable factors that affect trade. Given that the influence of variables that are bilateral and time-invariant —such as geographical distance, a common language, or a shared border— is absorbed by fixed bilateral effects, the estimated coefficients for these factors are not directly obtained in this specification of the model.

Exporter-time τ_{it} and importer-time φ_{jt} fixed effects represent all the factors that are specific to each country and time period and affect trade flows. These are included to control for inward and outward multilateral resistance, that is, third countries' barriers to trade that affect the costs of trade, mainly to account for factors such as relative prices, institutions, infrastructure, or legal factors that vary by country and over time, including the exporter's/importer's GDP. Consequently, the inclusion of MRT in the form of dummy variables for each exporter-time and importer-time pair absorbs the effects of the income of the trading countries. The inclusion of these three sets of fixed effects (bilateral, exporter-period, and importer-period) has been recommended in the literature as a suitable way of identifying the effects of RTAs on trade (Baier and Bergstrand, 2007; Yotov et al., 2016).

Even though it is common practice to estimate the gravity model in its log-linear form, there are many advantages to estimating the model in its multiplicative form using the Poisson Pseudo Maximum Likelihood Estimator (PPML), as originally suggested by Santos Silva and Tenreyro (2006).[16] First, the log-transformation of the dependent variable leads to the loss of the zero trade flows and when the zeros are not arbitrarily missing data or random rounding errors, they could carry important information. These zeros could be due to high trade barriers or regular rounding errors associated with small trade flows; as such, dropping these observations will produce inconsistent estimates.[17] While there are a number of ways to overcome

15 It is important to include this variable as agreements that include technology provisions could have a different effect on trade for all types of exports depending on whether the agreements are deep and comprehensive, or only shallow. The correlation between RTA_depth and RTA_tech is low.

16 For the implementation of this estimation method, the newly available Stata command ppml_panel_sg (Zylkin, 2017) was employed.

17 While the data extracted from UNCTAD did not contain any zeros, balancing the data to obtain all possible importer, exporter and year combinations led to a large number of observations for which trade values were missing, either because they were not reported or they were actually zero.

the problem of zero trade flows,[18] PPML is preferred here as it is straightforward in its application and avoids the theoretically inconsistent method of replacing zero trade flows with an arbitrary value. A second argument in favor of this approach is that, according to Santos Silva and Tenreyro (2006), estimating the gravity model in its log-linear form rather than in levels can lead to misleading conclusions in the presence of heteroskedasticity as the log transformation affects the disturbances. The PPML estimator resolves this issue, as it is valid under general forms of heteroskedasticity.

The rapid ongoing development of new techniques for estimating the model based on theoretical developments has given rise to a series of practical recommendations documented in Head and Mayer (2014) and more recently in Yotov et al. (2016). The authors also suggest proxying MRT and bilateral unobserved heterogeneity using the three abovementioned sets of fixed effects. In line with these developments, the specification for the structural gravity model is as follows:

$$X_{ijt} = Exp\left[\delta_{ij} + \tau_{it} + \varphi_{jt} + \gamma TP_{ijt} + \sum_k \beta_k RTA_{kijt}\right] * \varepsilon_{ijt} \tag{4}$$

where the variables are as described below Eqs. (2) and (3).

4.2 Data sources and variables

The data on total exports and exports disaggregated by technology intensity came from UNCTAD (unctadstat.org). The classification used here is based on Lall (2000) and divides products into three groups depending on their level of technology content: high (HT), medium (MT), and low (LT). The HT group contains products that use advanced technologies and change rapidly, which thus require significant investment in R&D and a focus on product design. Some examples are aircraft and telecommunication equipment, pharmaceutical products and medicaments (see Table 7 in the Appendix). The MT group includes capital goods and intermediate products that use skill-intensive technologies and form the basis for industrial activity in mature economies. They tend to include complex technologies with relatively high levels of R&D, require advanced skills, and extended periods of learning. Goods in the engineering and automotive subgroups require considerable interaction between firms to achieve technical efficiency. Finally, the LT group contains stable technologies that are already widespread. These technologies are used in capital equipment at the lower end of the range and are based on relatively simple skills. Many traded products in this group are homogenous and compete on price, and include textiles, garments and footwear. The labor costs of these tend to play a significant part in their competitiveness. As economies of scale and barriers to entry for these products are generally low, the end market tends to grow slowly, with income elasticities below one.

[18] Yotov et al. (2016) (p. 19) presents five possible solutions to this problem.

With regard to the data sources for the explanatory variables used in this paper, the data for GDP were obtained from the World Bank Development Indicators Database (World Bank, 2019), while data on distance, shared border, common language, colonial ties, geographic area, and access to the sea came from CEPII. The construction of RTA variables by type was explained in Sect. 3.

Table 1 provides an overview of the variables used in the model and the corresponding descriptive statistics: means, standard deviations, maximums, and minimums. The list of countries included can be found in the Appendix (Table 6).

5 Main results

Table 2 shows the results of Eq. (4) estimated with the dependent variable in levels using PPML, which is based on the theoretically justified gravity model and includes MRT. The results of the corresponding log–log specification in Eq. (3) are presented in the Appendix (Table 8), where the results of the linearized traditional specification of the gravity model are also shown for comparative purposes.[19]

Table 2 presents the results for total exports in column 1. When using the PPML method,[20] the estimated effects are generally larger than those obtained with the log–log model.[21] The results for the variables of interest (RTA_tech and RTA_notech) suggest that while RTAs containing provisions of this type increase total exports by 24%[22] for shallow agreements (RTA_depth = 0), RTAs without such provisions also show a significant effect on total exports, of slightly higher magnitude.[23] We also estimated the model with PPML eliminating zero trade flows, keeping the same number of observations as in the log–log model, and the results show that the effects of RTA_tech are smaller in magnitude (the RTA_tech coefficient is 0.081 instead of 0.215 for total exports).[24]

When the model is estimated for exports with different levels of technology content—HT, MT, and LT, according to the abovementioned UNCTAD classification—the results vary. For exports with HT content (in column 2, Table 2), agreements

[19] The first column in Table 8 presents the estimations using traditional gravity variables. In the second column, variables that vary by country are replaced by origin and destination fixed effects, and in the third column bilateral variables are replaced by dyadic fixed effects. The traditional gravity variables present the expected signs and magnitudes; the GDP coefficients are close to the theoretical value of one in column (1); distance, area and landlocked variables show negative and significant coefficients, and sharing a border, an official language or colonial ties all increase trade significantly, as expected. WTO membership, TRIPs and common currency all show positive and significant effects on total exports, which decrease in magnitude when controlling for country-time and pair fixed effects in column (4).

[20] The command ppml_panel_sg, written by Zylkin (2017), was used ("symmetric pair effects" option is appropriate for identification if all main variables are symmetric with respect to direction of trade, Zylkin post: Statalist 8th November 2017).

[21] According to Bergstrand et al. (2015), PPML estimates tend to be larger than OLS estimates for RTAs.

[22] Compared with 14% for RTA_tech in column 4, Table 8.

[23] As usual, the percentage increase in trade attributed to RTAs is obtained by applying the exponential (anti-log) to the estimated coefficient, subtracting 1, and multiplying by 100.

[24] Full results are available in the Appendix (Table 9).

Table 1 Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
Total USD value of exports (X)	697,428	293,086.7	4,059,546	0	5.04E+08
Exports HT (X_HT)	697,428	60,198.84	1,245,627	0	2.27E+08
Exports MT (X_MT)	697,428	63,212.08	910,406.4	0	8.50E+07
Exports LT (X_LT)	697,428	42,204.89	744,460.8	0	1.53E+08
Ln total exports	427,201	7.462	4.087	−6.908	20.038
Ln exports HT	305,137	5.493	4.070	−6.908	19.241
Ln exports MT	334,617	6.131	4.043	−6.908	18.258
Ln exports LT	349,748	5.552	3.995	−6.908	18.844
Ln GDP_exporter	646,215	23.685	2.375	16.395	30.523
Ln GDP_importer	643,634	23.652	2.399	16.216	30.523
Ln distance	697,428	8.737	0.822	0.632	9.899
Common language	697,428	0.147	0.354	0	1
Common border	697,428	0.016	0.124	0	1
Colonial ties	697,428	0.106	0.308	0	1
Ln area_exporter	697,428	11.458	2.511	3.332	16.117
Ln area_importer	697,428	11.389	2.583	2.302	16.116
Landlocked_exporter	697,428	0.203	0.403	0	1
Landlocked_importer	697,428	0.201	0.401	0	1
WTO membership	697,428	0.586	0.493	0	1
TRIPs	697,428	0.316	0.465	0	1
Common currency	661,704	0.012	0.109	0	1
RTA_tech (with technology provisions)	697,428	0.052	0.223	0	1
RTA_notech (without technology provisions)	697,428	0.033	0.178	0	1
RTA_depth	697,428	0.286	1.057	0	7

HT, MT and LT denote high, medium and low technology content, respectively. TRIPs takes the value of 1 from the year in which countries are first in compliance with TRIPs and 0 otherwise. WTO members were given different transition periods for the implementation of TRIPs laws and enforcement mechanisms. Developed countries were given one year, whereas developing countries and some transition economies were given five years (until 2000) and least developed countries initially had 11 years (until 2006), but the period was extended until 2013 for most products and even longer for a few sensitive products (pharmaceutical patents, undisclosed information protection). Exports are in thousands USD

containing only technology provisions have a significant effect in terms of stimulating export growth, whereas agreements without such provisions are less effective. More specifically, the point coefficient for RTA_tech indicates that adding technology provisions to an RTA increases trade in HT products by 21% (column 2, first row) independently of whether or not the RTA contains any other type of provisions. Indeed, RTA_depth is not statistically significant for HT products (column 2), and the same is the case for RTA_notech. This means that the partial effect on trade of adding technology provisions is around 15%, $[(\exp\{0.189-0.0526\}-1)*100]$, which we interpret as the direct effect, whereas the trade effect of eliminating trade policy barriers is around 6%.

Table 2 Estimation of the gravity model for export flows (PPML)

Dep. variable	(1) X_Total	(2) X_HT	(3) X_MT	(4) X_LT
Ind. variables				
RTA_tech	0.215***	0.189***	0.0266	0.165***
	(0.0318)	(0.0440)	(0.0359)	(0.0355)
RTA_notech	0.324***	0.0526	0.452***	0.118*
	(0.0576)	(0.0478)	(0.0503)	(0.0625)
RTA_depth	0.0441***	0.000976	0.0784***	0.0702***
	(0.00620)	(0.00735)	(0.00750)	(0.00781)
Common currency	0.779***	0.517***	0.667***	0.538***
	(0.0414)	(0.0418)	(0.0405)	(0.0349)
TRIPs	0.540***	−0.0680	0.185	0.597***
	(0.125)	(0.197)	(0.172)	(0.0922)
Observations	587,469	608,560	626,353	627,756
Pseudo R-squared	0.982	0.990	0.980	0.989

Standard errors in parentheses. $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$. Panel structural gravity estimation fixed effects included: exporter-year, importer-year, exporter-importer (symmetric). Clustered standard errors, clustered by exporter-importer (default). X denotes the value of exports. HT, MT and LT denote high, medium and low technology content, respectively. RTA_tech/_notech denote membership in Regional Trade Agreements with/without technology-related provisions. RTA_depth is an index that varies between 1 and 7, with higher numbers indicating that more provisions are included

The results for exports with MT content are shown in column3 of Table 2. The effect of RTA_tech is positive and small for shallow RTAs, when RTA_depth = 0, and lower in magnitude than the effect of RTA_notech, but for RTAs with more than 1 provision type (RTA_depth = 2–7) the effect is significant and sizable. For those with LT content, the effect of RTA_tech is statistically significant even for shallow agreements and adds a 5% increase to the effect of RTA_notech (see column 4 in Table 2). The results also show that the coefficient of RTA_depth is positive and significant for MT and LT groups, indicating that deeper RTAs promote exports with MT content the most. In this estimation, TRIPs and WTO present collinearity problems and cannot be estimated in the same model. We show the results including TRIPs since it is more relevant in this setting. The estimated coefficient for TRIPs indicates that total exports and exports with LT content are positively affected, whereas the effect is not statistically significant for exports with MT and HT content. Finally, countries in a currency union trade substantially more than others, with the effect being slightly higher for total exports and exports with MT content.

Since the effects estimated might be heterogeneous, and since the types of technology clause vary depending on whether the agreement is between developed countries and developing countries or between countries with similar income levels, we now proceed to evaluate the effect on trade by groups of countries and for each type of clause separately. The resulting information will enable us to identify the heterogeneity of the effects.

5.1 Heterogeneous effects for different groups of countries and technology provisions

In this section, we present our estimation of the gravity model after first identifying whether the trade flow is between developed countries (North: N) or developing ones (South: S), looking at the four possible origin/destination combinations (NS; NN; SN; and SS).[25] Specification (4) is augmented with interactions between RTA_tech and the direction of trade flows. The results are presented in Table 3. The first rows show the coefficients obtained for the interaction terms. It can be observed in the first row that shallow RTAs (RTA_depth = 0) with technology provisions between developed countries (NN) have a positive and significant effect on trade in high technology goods, but not on MT and LT goods. For trade between developing countries (SS) there is also an extra trade effect above the one obtained for RTA_notech, in this case for all types of goods. However, for agreements between developed and developing countries, the direct effect on trade of having technology-related provisions is negative for shallow RTAs, indicating that only when the depth of the agreements is considerable (RTA_depth > = 4) can any indirect trade effect be magnified. The marginal effects of adding technology provisions for different levels of RTA depth are shown in Table 4.

The results shown in Table 3 also suggests that RTAs with technology provisions benefit exports between developing countries (SS) proportionately more, as indicated by the coefficient of RTA_tech_SS. They also benefit exports of goods with LT content relatively more, although they do still benefit HT and MT exports when the agreement includes technology provisions and exports go from one developing country to another.

Table 4 shows that the incremental effect on exports of adding technology-related provisions is substantial for SS trade flows and increase with the depth of the RTAs (number of additional provisions on other subjects). For NN trade, the marginal effects are also positive for all types of goods when the depth of the RTA is at least 4, whereas for NS and SN negative marginal effects are shown for less inclusive RTAs (RTA_depth < 4). This means that the short-run effects on trade of including technology-related provisions could lead to lower exports if the RTAs do not also regulate product, labor and environmental standards, for example. Finally, for RTAs of maximum depth, most marginal effects are shown to be positive, and it is only

[25] We use the United Nations definition, which for 2017 lists developed countries as being Australia (AUS), Austria (AUT), Bulgaria (BGR), Canada (CAN), Croatia (HRV), Cyprus (CYP), Czech Rep. (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Iceland (ISL), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Latvia (LVA), Lithuania (LTU), Malta (MLT), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Poland (POL), Portugal (PRT), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), and United States (USA).

Table 3 Estimation of the model with heterogeneous effects by income level

Dep. Var.:	(1) X_Total	(2) X_HT	(3) X_MT	(4) X_LT
Ind. variables				
RTA_tech_NN	0.352***	0.143***	0.0788	0.0738
	(0.0577)	(0.0513)	(0.0502)	(0.0466)
RTA_tech_NS	−0.275***	−0.339***	−0.559***	−0.434***
	(0.0431)	(0.0875)	(0.0607)	(0.0541)
RTA_tech_SN	−0.256***	−0.0964**	−0.438***	−0.401***
	(0.0406)	(0.0451)	(0.0434)	(0.0485)
RTA_tech_SS	0.576***	0.536***	0.490***	0.700***
	(0.0424)	(0.0706)	(0.0453)	(0.0491)
RTA_notech	0.209***	−0.0261	0.351***	0.0347
	(0.0564)	(0.0498)	(0.0489)	(0.0615)
RTA_depth	0.0879***	0.0345***	0.129***	0.122***
	(0.00626)	(0.00782)	(0.00744)	(0.00770)
CU	0.700***	0.481***	0.598***	0.470***
	(0.0397)	(0.0400)	(0.0391)	(0.0342)
TRIPs	0.547***	−0.0294	0.236	0.599***
	(0.117)	(0.188)	(0.161)	(0.0896)
Observations	587,469	608,560	626,353	627,756
R-squared	0.982	0.990	0.981	0.989

Standard errors in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$. Panel structural gravity estimation fixed effects included: exporter-year, importer-year, exporter-importer (symmetric). Clustered standard errors, clustered by exporter-importer (default). The coefficients of TRIPs, RTA_depth and Common currency variables are not shown to save space. Flow identifies whether the trade flow is between developed countries (North: N) or developing ones (South: S). X denotes the value of exports. HT, MT and LT denote high, medium and low technology content, respectively. RTA_tech/_notech denote membership in Regional Trade Agreements with/without technology-related provisions

for exports from developed to developing countries (NS) that some small negative effects are found.

Next, we differentiate between each of the four possible technology clause types. The gravity model is estimated with each provision relating to technology and innovation included separately in a single model for total exports and exports of HT, MT and LT goods. The aim is to ascertain whether the different types of provisions have a different direct effect on exports. The results, shown in Table 5, indicate that we cannot accept that the RTA with provisions affects exports equally for each type of provision. In particular, for total exports (column 1) RTAs with provisions on intellectual property rights and patents increase exports significantly more than RTAs without such provisions, whereas those with technology transfer, technical cooperation or R&D provisions show a

Table 4 Marginal effects of adding technology-related provisions

RTA_tech	X_HT	X_MT	X_LT
Trade flow			
RTA_depth = 2			
NN	0.238	−0.014	0.283
NS	−0.244	−0.652	−0.225
SN	−0.001	−0.531	−0.192
SS	0.631	0.397	0.909
RTA_depth = 4			
NN	0.307	0.244	0.527
NS	−0.175	−0.394	0.019
SN	0.068	−0.273	0.052
SS	0.700	0.655	1.153
RTA_depth = 7			
NN	0.411	0.631	0.893
NS	−0.071	−0.007	0.385
SN	0.171	0.114	0.418
SS	0.804	1.042	1.519

Effects calculated using the coefficients estimated in Table 3

negative coefficient, indicating that for shallow agreements the addition of those provisions does not magnify the trade effect of basic RTAs; on the contrary, they reduce it. For HT goods, both intellectual property rights and technical cooperation seem to exert a positive effect on exports, which is not present for RTAs without technology provisions (RTA_notech is not statistically significant in column 2). However, adding technology transfer provisions seems to decrease HT exports, perhaps due to the fact that it will facilitate importers' specialization in the production and exports of these goods. Concerning MT and LT exports, it also seems in this case that the most influential provisions are those concerning patents and intellectual property; and once again, the additional trade effect is positive and slightly higher than for HT goods. However, adding provisions in the other three categories considered does seem to reduce exports.

5.2 Robustness checks

As alternatives to the estimations presented here, the model was estimated for time intervals as suggested in Yotov et al. (2016) and the results for the target variables were practically unchanged. Table 10 shows the results using data for every three years.

Second, as suggested by Baier and Bergstrand (2007) to test for the potential endogeneity of the trade policy variable, we have estimated the model including 4 leads of the RTA variables. The results were used to test for the joint significance of the 4 leads of the RTA variables.[26] The fact that the sum of the t+1 to t+4

[26] Using a test of linear combinations of the coefficients: *lincom* in Stata. Results available upon request.

Table 5 Estimation results for the four types of technology provisions

Dep. Var.:	(1) X_Total	(2) X_HT	(3) X_MT	(4) X_LT
Ind. variables				
Technical cooperation	−0.135***	0.0923*	−0.0769*	−0.130***
	(0.0421)	(0.0547)	(0.0414)	(0.0466)
Technology transfer	−0.137***	−0.343***	−0.242***	−0.151***
	(0.0439)	(0.0585)	(0.0498)	(0.0512)
Research and development	−0.188***	0.0496	−0.129**	−0.356***
	(0.0453)	(0.0685)	(0.0520)	(0.0528)
Patents and intellectual property	0.433***	0.217***	0.240***	0.415***
	(0.0444)	(0.0547)	(0.0430)	(0.0466)
RTA_notech	0.293***	0.0156	0.441***	0.0824
	(0.0571)	(0.0483)	(0.0495)	(0.0617)
RTA_depth	0.0525***	0.0132*	0.0841***	0.0849***
	(0.00667)	(0.00746)	(0.00770)	(0.00809)
CU	0.754***	0.502***	0.652***	0.517***
	(0.0411)	(0.0405)	(0.0399)	(0.0347)
TRIPs	0.526***	−0.0694	0.194	0.590***
	(0.120)	(0.193)	(0.169)	(0.0921)
Observations	587,469	608,560	626,353	627,756
R-squared	0.981	0.990	0.979	0.989

Standard errors in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$. Panel structural gravity estimation fixed effects included: exporter-year, importer-year, exporter-importer (symmetric). Clustered standard errors, clustered by exporter-importer (default). The coefficients of TRIPs, RTA_depth and Common currency variables are not shown to save space. X denotes the value of exports. HT, MT and LT denote high, medium and low technology-content, respectively. RTA_tech/_notech denote membership in Regional Trade Agreements with/without technology-related provisions

coefficients is not statistically significant indicates that we are effectively controlling for endogeneity using bilateral time-invariant fixed effects. Moreover, we adopt the strategy proposed by the same authors of incorporating the RTA variable with a number of different lags to consider the effects of phasing in trade agreements; the estimated coefficients indicate that the effects materialized between 4 and 8 years after the entry into force of the RTA, depending on the type of goods traded.

Third, we have replicated the results in Campi and Dueñas (2019) using the gravity model with the dependent variable in logarithms and with pair fixed effects, but without MRT. The results, reported in Table 11, show that the RTA coefficient is very similar to the one obtained by those authors, whereas the coefficients for the RTA with and without intellectual property provisions differ. We obtained a positive and significant effect for the RTA with intellectual property provisions and a not statistically significant coefficient for RTA without, whereas they reported a stronger and positive effect for RTA without intellectual property provisions. This could be due to the fact that the number of observations in our estimations is almost double that used by Campi and Dueñas (2019), despite the fact that we restricted the sample of countries to match their sample. More research is needed to find the cause of the divergence in the results.

Finally, we have replicated the results in Dhingra et al. (2018) for gross exports of goods using high dimensional fixed effects with 2-year (as in their baseline model) and 4-year time intervals. The results are shown in Table 12. Columns 1 and 2 are comparable to those in columns 1 and 4 of Table 6 (Dhingra et al., 2018, page 25). Columns 4 to 8 replicate their Table 12 (Dhingra et al., 2018, page 38). We confirm that for their sample of 43 countries the coefficient on intellectual property provisions is not statistically significant, whereas in the extended sample a positive and significant effect is found for it, as it is the case in our estimations.

6 Conclusions

Including innovation provisions for direct technology transfer in RTAs has different effects on exports depending on the direction of trade, the level of development of the countries of origin and destination, and the type of clause included in the agreement. The main results of this study indicate that RTAs that contain technology-related provisions generate a significantly higher aggregate volume of trade than RTAs that do not, after controlling for the depth of the agreements. When all countries are considered, for those that ratify RTAs with such provisions rather than those without, it is exports of technology-intensive goods that increase the most.

Patterns found in the results indicate which countries or sectors should benefit from the inclusion of technology provisions. SS agreements have positive effects on exports of HT, MT and LT, which are higher in magnitude for LT exports; this finding reflects their relatively low level of technological development. In NN agreements, the effects of RTAs are less pronounced. For RTAs between countries with different levels of development the addition of technology-related provision could have detrimental effects on exports in the short run, but this depends on the depth of the RTAs. For deep and comprehensive trade agreements the additional trade effect tends to be positive for almost all trade flows, with only exports from developed to developing countries showing small negative effects. The good news is that, for the most part, our results support the inclusion of intellectual property related provisions in the RTAs, given that those provisions seem to exert an additional positive effect on trade, even for shallow RTAs. Conversely, provisions related to technology transfer, R&D and technical cooperation might be looser and hence less effective.

In certain circumstances, the existence of provisions may not be enough in itself to guarantee effective technology transfer. To complement them, it may be necessary to create appropriate enforcement mechanisms to build on the vague provisions in trade agreements. These might take the form of monitoring committees formed of representatives from both parties whose sole function is to ensure compliance with these provisions. Establishing binational parliamentary committees is another such possibility.[27]

[27] This was the case for the Chile–China agreement, following which the Permanent Binational Commission and the Mechanism for Strategic Dialogue for Economic Cooperation and Coordination were created. For more examples, see Chelala (2018).

The WTO laid the groundwork for technology transfer through TRIPs and has urged developed countries to create reports to document the steps they have taken to apply the articles on cooperation in their relations with lower-income countries. In line with these commitments, it is important to continuously assess the impact of agreements, especially the aspects that relate to technology transfer, an issue which is by nature constantly changing. By estimating how RTAs containing different types of innovation and technology transfer provisions affect trade, this study is intended as a step in this direction.

The main results suggest that it is important for agreements to include such provisions, particularly if they are to be effective at increasing medium-technology exports from new industrialized countries to developing countries, which in turn facilitates knowledge and technology transfer between countries and generates technology spillovers.

To distinguish between the effects of the provisions depending on the enforcement mechanisms that are set out in the RTAs, this study could be extended by classifying RTA provisions according to how stringently they are enforced. Alternatively, a more straightforward approach could be to see whether effects vary depending on levels of rule of law and the effectiveness of governance in exporter countries.

We also leave for future research the estimation of the effects of RTAs containing innovation and technology provisions on the technological level of the countries that ratify such agreements, distinguishing between the pure trade effect effects and those that are due to direct technology transfer. To that end, the trade predictions obtained from the gravity model could be included, together with proxies for participation in RTAs with those provisions, in a model of the determinants of R&D expenditure and innovative activity.

Appendix

See Tables 6, 7, 8, 9, 10, 11, 12 and Figs. 3, 4, 5.

Table 6 List of countries

Afghanistan	Czech Rep	Kuwait	Rwanda
Albania	Cote d'Ivoire	Kyrgyzstan	Samoa
Algeria	People's Rep. of Korea	Lao People's Dem. Rep	Sao Tome and Principe
Angola	Denmark	Latvia	Saudi Arabia
Antigua and Barbuda	Djibouti	Lebanon	Senegal
Argentina	Dominica	Lesotho	Seychelles
Armenia	Dominican Rep	Liberia	Sierra Leone
Australia	Ecuador	Libya	Singapore
Austria	Egypt	Lithuania	Slovakia
Azerbaijan	El Salvador	Luxembourg	Slovenia
Bahamas	Equatorial Guinea	Madagascar	Solomon Isds
Bahrain	Eritrea	Malawi	Somalia
Bangladesh	Estonia	Malaysia	South Africa
Barbados	Ethiopia	Maldives	Spain
Belarus	Fiji	Mali	Sri Lanka
Belize	Finland	Malta	Sudan
Benin	France	Mauritania	Suriname
Bermuda	Gabon	Mauritius	Swaziland
Bhutan	Gambia	Mexico	Sweden
Bolivia	Georgia	Mongolia	Switzerland
Bosnia Herzegovina	Germany	Morocco	Syria
Botswana	Ghana	Mozambique	TFYR of Macedonia
Brazil	Greece	Myanmar	Tajikistan
Brunei Darussalam	Greenland	Namibia	Thailand
Bulgaria	Guatemala	Nepal	Togo
Burkina Faso	Guinea	Netherlands	Tonga
Burundi	Guinea-Bissau	New Zealand	Trinidad and Tobago
Cambodia	Guyana	Nicaragua	Tunisia
Cameroon	Haiti	Niger	Turkey
Canada	Honduras	Nigeria	Turkmenistan
Cape Verde	Hungary	Norway	Tuvalu
Central African Rep	Iceland	Oman	USA
Chad	Indonesia	Pakistan	Uganda
Chile	Iran	Palau	Ukraine
China	Iraq	Panama	United Arab Emirates
China, Hong Kong SAR	Ireland	Papua New Guinea	United Kingdom
China, Macao SAR	Israel	Paraguay	Uruguay
Colombia	Italy	Peru	Uzbekistan
Comoros	Jamaica	Philippines	Vanuatu
Congo	Japan	Poland	Venezuela
Costa Rica	Jordan	Portugal	Viet Nam
Croatia	Kazakhstan	Qatar	Yemen
Cuba	Kenya	Rep. of Korea	Zambia
Cyprus	Kiribati	Rep. of Moldova	Zimbabwe

Table 7 Classification of goods

Lall (2000) Classification from UNCTAD
DC04 Low technology manufactures: textile, garment and footwear
611 Leather
612 Manufactures of leather, n.e.s.; saddlery and harness
613 Furskins, tanned or dressed, excluding those of 8483
651 Textile yarn
652 Cotton fabrics, woven
654 Other textile fabrics, woven
655 Knitted or crocheted fabrics, n.e.s
656 Tulles, trimmings, lace, ribbons and other small wares
657 Special yarn, special textile fabrics and related
658 Made-up articles, of textile materials, n.e.s
659 Floor coverings, etc
831 Travel goods, handbags and similar containers
841 Men's clothing of textile fabrics, not knitted
842 Women's clothing, of textile fabrics
843 Men's or boys' clothing, of textile, knitted, croche
844 Women's clothing, of textile, knitted or crocheted
845 Articles of apparel, of textile fabrics, n.e.s
846 Clothing accessories, of textile fabrics
848 Articles of apparel, clothing access., excluding textile
851 Footwear
LDC05 Low technology manufactures: other products
642 Paper and paperboard, cut to shape or size, article
665 Glassware
666 Pottery
673 Flat-rolled prod., iron, non-alloy steel, not coated
674 Flat-rolled prod., iron, non-alloy steel, coated, clad
675 Flat-rolled products of alloy steel
676 Iron and steel bars, rods, angles, shapes and sections
677 Rails and railway track construction mat., iron, steel
678 Wire of iron or steel
691 Structures and parts, n.e.s., of iron, steel, aluminium
692 Metal containers for storage or transport
693 Wire products (excluding electrical) and fencing grills
694 Nails, screws, nuts, bolts, rivets and the like, of metal
695 Tools for use in the hand or in machine
696 Cutlery
697 Household equipment of base metal, n.e.s
699 Manufactures of base metal, n.e.s.

Table 7 (continued)

Lall (2000) Classification from UNCTAD
821 Furniture and parts
893 Articles, n.e.s., of plastics
894 Baby carriages, toys, games and sporting goods
895 Office and stationery supplies, n.e.s
897 Jewellery and articles of precious materia., n.e.s
898 Musical instruments, parts; records, tapes and similar
899 Miscellaneous manufactured articles, n.e.s
LDC06 Medium technology manufactures: automotive
781 Motor vehicles for the transport of persons
782 Motor vehic. for transport of goods, special purpo
783 Road motor vehicles, n.e.s
784 Parts and accessories of vehicles of 722, 781, 782, 783
785 Motorcycles and cycles
LDC07 Medium technology manufactures: process
266 Synthetic fibres suitable for spinning
267 Other man-made fibres suitable for spinning
512 Alcohols, phenols, halogenat., sulfonat., nitrat. der
513 Carboxylic acids, anhydrides, halides, per.; derivati
533 Pigments, paints, varnishes and related materials
553 Perfumery, cosmetics or toilet prepar. (excluding soaps)
554 Soaps, cleansing and polishing preparations
562 Fertilizers (other than those of group 272)
571 Polymers of ethylene, in primary forms
572 Polymers of styrene, in primary forms
573 Polymers of vinyl chloride or halogenated olefins
574 Polyethers, epoxide resins; polycarbonat., polyesters
575 Other plastics, in primary forms
579 Waste, parings and scrap, of plastics
581 Tubes, pipes and hoses of plastics
582 Plates, sheets, films, foil and strip, of plastics
583 Monofilaments, of plastics, cross-section > 1 mm
591 Insecticides and similar products, for retail sale
593 Explosives and pyrotechnic products
597 Prepared addit. for miner. oils; lubricat., de-icing
598 Miscellaneous chemical products, n.e.s
653 Fabrics, woven, of man-made fabrics
671 Pig iron and spiegeleisen, sponge iron, powder and granu
672 Ingots, primary forms, of iron or steel; semi-finis
679 Tubes, pipes and hollow profiles, fittings, iron, steel

Table 7 (continued)

Lall (2000) Classification from UNCTAD
786 Trailers and semi-trailers
791 Railway vehicles and associated equipment
882 Cinematographic and photographic supplies
LDC08 Medium technology manufactures: engineering
711 Vapour generating boilers, auxiliary plant parts
713 Internal combustion piston engines, parts, n.e.s
714 Engines and motors, non-electric; parts, n.e.s
721 Agricultural machinery (excluding tractors) and parts
722 Tractors (excluding those of 71,414 and 74,415)
723 Civil engineering and contractors' plant and equipment
724 Textile and leather machinery, and parts thereof, n.e.s
725 Paper mill, pulp mill machinery; paper articles man
726 Printing and bookbinding machinery, and parts thereof
727 Food-processing machines (excluding domestic)
728 Other machinery for particular industries, n.e.s
731 Machine-tools working by removing material
733 Mach.-tools for working metal, excluding removing mate
735 Parts, n.e.s., and accessories for machines of 731, 733
737 Metalworking machinery (excluding machine-tools) and parts
741 Heating and cooling equipment and parts thereof, n.e.s
742 Pumps for liquids
743 Pumps (excluding liquid), gas compressors and fans; centr
744 Mechanical handling equipment, and parts, n.e.s
745 Other non-electr. machinery, tools and mechan. appar
746 Ball or roller bearings
747 Appliances for pipes, boiler shells, tanks, vats, etc
748 Transmis. shafts
749 Non-electric parts and accessor. of machinery, n.e.s
762 Radio-broadcast receivers, whether or not combined
763 Sound recorders or reproducers
772 Apparatus for electrical circuits; board, panels
773 Equipment for distributing electricity, n.e.s
775 Household type equipment, electrical or not, n.e.s
793 Ships, boats and floating structures
811 Prefabricated buildings
812 Sanitary, plumbing, heating fixtures, fittings, n.e.s
813 Lighting fixtures and fittings, n.e.s
872 Instruments and appliances, n.e.s., for medical, etc
873 Meters and counters, n.e.s

Table 7 (continued)

Lall (2000) Classification from UNCTAD
884 Optical goods, n.e.s
LDC09 High technology manufactures: electronic and electrical
716 Rotating electric plant and parts thereof, n.e.s
718 Other power generating machinery and parts, n.e.s
751Office machines
752Automatic data processing machines, n.e.s
759 Parts, accessories for machines of groups 751, 752
761 Television receivers, whether or not combined
764 Telecommunication equipment, n.e.s.; and parts, n.e.s
771 Electric power machinery, and parts thereof
774 Electro-diagnostic appa. for medical sciences, etc
776 Cathode valves and tubes
778 Electrical machinery and apparatus, n.e.s
LDC10 High technology manufactures: other
525 Radio-actives and associated materials
541Medicinal and pharmaceutical products, excluding 542
542Medicaments (incl. veterinary medicaments)
712 Steam turbines and other vapour turbin., parts, n.e.s
792 Aircraft and associated equipment; spacecraft, etc
871 Optical instruments and apparatus, n.e.s
874 Measuring, analysing and controlling apparatus, n.e.s
881 Photographic apparatus and equipment, n.e.s

Source: https://unctadstat.unctad.org

Table 8 Estimation of the traditional log-linearized gravity model for export flows

Gravity model fixed effects (FE)	Traditional time FE	Origin, destination, time FE	Pair and time FE	Pair, origin-time, destination-time FE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable	lnX_total	lnX_total	LX_total	lnX_total	lnX_HT	LX_MT	lnX_LT
Independent variables							
RTA_tech	0.791***	1.067***	0.236***	0.134***	−0.036	0.221***	0.153***
	(0.060)	(0.054)	(0.032)	(0.020)	(0.027)	(0.028)	(0.024)
RTA_notech	1.126***	0.982***	−0.003	−0.055**	−0.116***	0.061**	−0.032
	(0.068)	(0.064)	(0.037)	(0.023)	(0.029)	(0.030)	(0.024)
RTA_depth	−0.037***	−0.118***	0.021***	0.006	0.017***	−0.018***	0.003
	(0.012)	(0.011)	(0.006)	(0.004)	(0.006)	(0.006)	(0.005)
WTO members	0.285***	0.220***	0.192***	0.135***	0.044	0.095*	0.075*
	(0.030)	(0.034)	(0.025)	(0.035)	(0.055)	(0.055)	(0.044)
TRIPs	0.233***	0.227***	0.132***	0.063**	0.192***	0.116***	0.082***
	(0.030)	(0.030)	(0.021)	(0.025)	(0.034)	(0.042)	(0.028)
Common currency	0.387***	0.179*	0.182***	0.165***	0.302***	0.151***	0.273***
	(0.097)	(0.095)	(0.033)	(0.024)	(0.039)	(0.035)	(0.029)
Ln GDP_exporter	1.228***	0.309***	0.431***				
	(0.006)	(0.024)	(0.023)				
Ln GDP_importer	0.976***	0.727***	0.811***				
	(0.007)	(0.020)	(0.018)				
Ln distance	−1.149***	−1.450***					
	(0.017)	(0.019)					
Common language	0.709***	0.690***					
	(0.037)	(0.038)					
Common border	0.978***	0.615***					
	(0.099)	(0.098)					

Table 8 (continued)

Gravity model fixed effects (FE)	Traditional time FE	Origin, destination, time FE	Pair and time FE	Pair, origin-time, destination-time FE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable	lnX_total	lnX_total	LX_total	lnX_total	lnX_HT	LX_MT	lnX_LT
Colonial ties	0.844***	0.875***					
	(0.053)	(0.048)					
Ln Area_exporter	−0.083***						
	(0.006)						
Ln Area_importer	−0.011*						
	(0.007)						
Landlocked_exporter	−0.500***						
	(0.033)						
Landlocked_importer	−0.408***						
	(0.032)						
Observations	387,180	387,180	387,180	402,398	285,565	314,413	329,052
Adjusted R-squared	0.670	0.740	0.153	0.879	0.860	0.837	0.868

Robust standard errors clustered by pair (exporter-importer) in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$. LnX denotes the natural log of the monetary value of exports. HT, MT and LT denote high, medium and low technology content, respectively. The number of bilateral trade flows included in columns (1) to (3) is 27,242. Ln denotes natural logs. RTA_tech/_notech denote membership in Regional Trade Agreements with/without technology-related provisions and RTA_depth is an index that varies between 1 and 7, with higher numbers indicating that more provisions are included

Table 9 Results excluding zero trade flows (PPML)

Dep. Var.:	(1) X_Total	(2) X_HT	(3) X_MT	(4) X_LT
Ind. variables				
RTA_tech	0.0807***	0.171***	−0.000764	0.129***
	(0.0270)	(0.0439)	(0.0358)	(0.0351)
RTA_notech	0.323***	0.0419	0.428***	0.104*
	(0.0526)	(0.0477)	(0.0498)	(0.0618)
RTA_depth	0.0340***	0.00294	0.0818***	0.0755***
	(0.00535)	(0.00732)	(0.00746)	(0.00781)
Common currency	0.215***	0.515***	0.663***	0.536***
	(0.0248)	(0.0417)	(0.0405)	(0.0350)
TRIPs	0.451***	−0.0526	0.197	0.626***
	(0.114)	(0.198)	(0.175)	(0.0922)
Observations	402,398	285,565	314,413	329,052
R-squared	0.988	0.990	0.981	0.990

Robust standard errors clustered by pair (exporter-importer) in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$. Panel structural gravity estimation fixed effects included: exporter-year, importer-year, exporter-importer (symmetric). RTA_tech/_notech denotes membership in Regional Trade Agreements with/without technology-related provisions. X denotes the value of exports.HT, MT and LT denote high, medium and low technology content, respectively

Table 10 Intervals every three years and by export type (PPML)

Dep. Var.:	(1) X_Total	(2) X_HT	(3) X_MT	(4) X_LT
Ind. Variables				
RTA_tech	0.173***	0.153***	0.0196	0.183***
	(0.0327)	(0.0433)	(0.0363)	(0.0367)
RTA_notech	0.291***	0.0263	0.433***	0.112*
	(0.0571)	(0.0474)	(0.0515)	(0.0642)
RTA_depth	0.0498***	0.00292	0.0801***	0.0638***
	(0.00635)	(0.00735)	(0.00752)	(0.00786)
Common currency	0.694***	0.454***	0.618***	0.488***
	(0.0424)	(0.0427)	(0.0410)	(0.0350)
TRIPs	0.579***	−0.122	0.231	0.649***
	(0.138)	(0.216)	(0.178)	(0.0978)
Observations	222,259	219,698	229,662	230,140
R-Squared	0.982	0.991	0.981	0.989

Robust standard errors clustered by pair (exporter-importer) in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$. Panel structural gravity estimation fixed effects included: exporter-year, importer-year, exporter-importer (symmetric). RTA_tech/_notech denotes membership in Regional Trade Agreements with/without technology-related provisions. X denotes the value of exports. HT, MT and LT denote high, medium and low technology content, respectively

Table 11 Replication of Campi and Dueñas (2019)

Dep. Variable	(1) lnX_Total ij FE	(2) lnX_Total ij FE	(3) lnX_Total ij FE	(4) lnX_Total ij FE	(5) lnX_Total ij FE	(6) lnX_Total ij FE
Independent variables						
RTA	0.085***					
	(0.022)					
RTA_noIP		−0.068**		−0.056*	−0.056*	−0.057*
		(0.033)		(0.033)	(0.030)	(0.030)
RTA_IP			0.163***	0.161***	0.127***	0.135***
			(0.028)	(0.028)	(0.030)	(0.030)
L5. RTA_noIP					0.005	0.008
					(0.033)	(0.033)
L5. RTA_IP					0.088***	0.096***
					(0.028)	(0.028)
lrGDP_exp	1.103***	1.103***	1.111***	1.113***	0.981***	0.966***
	(0.054)	(0.054)	(0.054)	(0.054)	(0.058)	(0.058)
lrGDP_imp	1.248***	1.248***	1.255***	1.257***	1.398***	1.385***
	(0.046)	(0.046)	(0.046)	(0.046)	(0.048)	(0.048)
hc_imp	0.339***	0.345***	0.328***	0.328***	0.109	0.073
	(0.094)	(0.094)	(0.094)	(0.094)	(0.107)	(0.106)
hc_exp	0.372***	0.372***	0.365***	0.363***	0.119	0.083
	(0.100)	(0.100)	(0.100)	(0.100)	(0.110)	(0.109)
TRIPs						0.387***
						(0.038)
Observations	223,018	223,018	223,018	223,018	168,582	168,582
Number of id	13,730	13,730	13,730	13,730	13,694	13,694
Adjusted R-squared	0.211	0.211	0.211	0.211	0.183	0.184

Table 12 Results using Dhingra et al. (2018) sample and this paper's sample

	WIOD Sample of 43 countries (2001–2014)						Countries in Table 6 (1995–2014)		
Dep. Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LnX_Total	2 years intervals			4 years intervals			4 years intervals		
Ind. Variables									
RTA	−0.028	−0.038	−0.027	−0.054	−0.244***	−0.197*	0.067***	−0.002	−0.050
	(0.032)	(0.039)	(0.043)	(0.063)	(0.093)	(0.102)	(0.022)	(0.033)	(0.042)
RTA_depth		0.025*	0.027*		0.060***	0.064***		0.020***	0.016**
		(0.013)	(0.015)		(0.022)	(0.024)		(0.008)	(0.008)
Intellectual Property			−0.029			−0.086			0.092*
			(0.070)			(0.098)			(0.048)
WTO									0.138**
									(0.064)
TRIPs									0.092**
									(0.047)
Common Currency									0.124***
									(0.047)
Observations	14,600	14,600	14,600	8,297	8,297	8,297	112,208	112,208	112,134
Adjusted R-squared	0.935	0.935	0.935	0.933	0.933	0.933	0.873	0.873	0.873

Robust standard errors clustered by pair (exporter-importer) in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$. Ln denotes natural logs. RTA/_depth denote membership in Regional Trade Agreements /with Intellectual Property-related provisions and RTA_depth is an index that varies between 1 and 7, with higher numbers indicating that more provisions are included. Panel structural gravity estimation fixed effects included: exporter-year, importer-year, exporter-importer. LnX_total denotes the natural log of the monetary value of aggregated exports

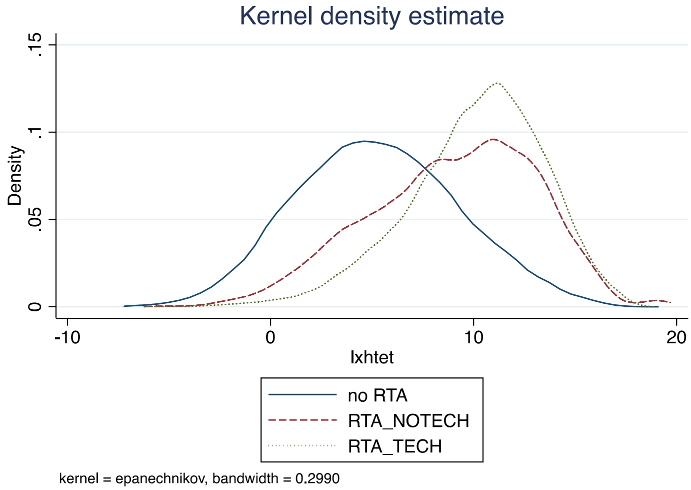

Fig. 3 Distribution of high-technology-content exports by type of agreement. *Source*: Compiled by the authors based on RTAs and exports (UNCTAD). Lexp is ln of high-tech exports. Years 1995 to 2017

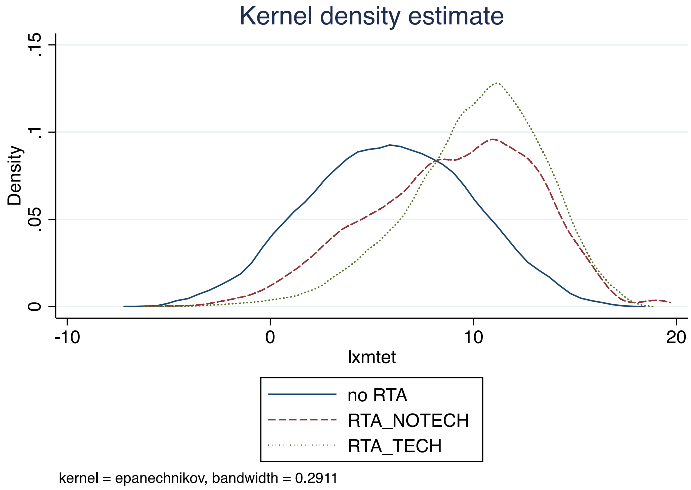

Fig. 4 Distribution of medium-technology-content exports by type of agreement. *Source:* Compiled by the authors based on RTAs and exports (UNCTAD). Lxmtet is ln of medium-tech exports. Years 1995 to 2017

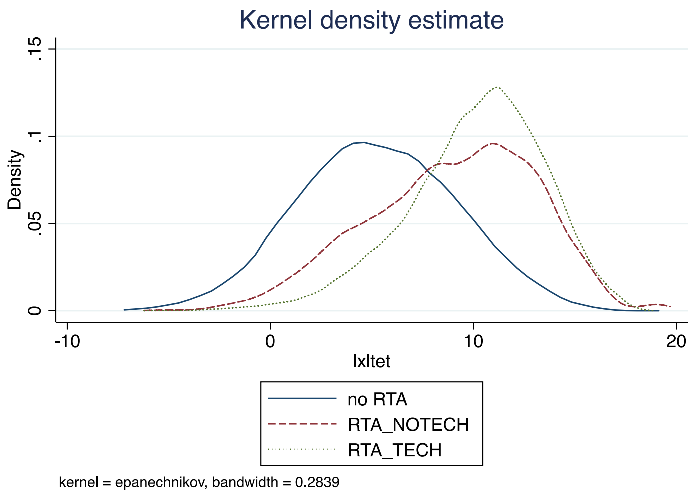

Fig. 5 Distribution of low-technology-content exports by type of agreement. *Source:* Compiled by the authors based on RTAs and exports (UNCTAD). Lxltet is ln of low-tech exports. Years 1995 to 2017

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