Chapter 7

Do Deep Regional Trade Agreements Enhance International Technology Spillovers? Depth, Breadth, and Heterogeneity

7.1 Introduction

In Chap. 5, we examine the relationship between bilateral trade patterns and international technology spillovers. In Chap. 6, we analyze how horizontal and vertical foreign direct investment (FDI) of multinational enterprises (MNEs) affects technology spillovers between themselves and firms in host countries. Both chapters analyze the issues from theoretical and empirical points of view. Each chapter shows that international trade or FDI is an important channel of international technology spillovers, but the effect on them is heterogeneous, depending on the type of trade patterns or the structure of FDI. In both chapters we measure technology spillovers using patent citation data.

In this chapter, we shed light on the role of deep regional trade agreements (RTAs) in international technology spillovers. As is well known in the field of international economics, trade creation and trade diversion are the most popular effects of signing an RTA (Viner 1950). The dynamic effects of RTAs such as the effects on technology adoption and technology diffusion have been examined by relatively recent studies (e.g., Bustos 2011; Das and Andriamananjara 2006; Ederington and McCalman 2008; Schiff and Wang 2003).

As Jinji et al. (2019a) argue, RTAs may facilitate cross-border technology spillovers both directly and indirectly. The indirect effects of RTAs on cross-border technology spillovers are through international trade in goods and FDI. Since RTAs, particularly deep RTAs with investment provisions, stimulate international trade and FDI, they can facilitate cross-border technology spillovers through an increase in bilateral trade and FDI. A more direct link between RTAs and cross-border technology spillovers may arise from the deep nature of recent RTAs. As examined in Chap. 2, recent RTAs tend to be deeper than old ones. Many RTAs include provisions related to technology, such as trade-related aspects of intellectual property rights (TRIPS), intellectual property right (IPR), innovation policy, and research and development (R&D). Moreover, some RTAs explicitly include provisions that stimulate

technology spillovers. For example, the United States-Peru Free Trade Agreement includes a provision on the promotion of innovation and technological development (Article 16.12), which encourages the engagement in collaborative scientific research projects and transfer of technology.

Using patent citations as a proxy for technology spillovers, Jinji et al. (2019a) empirically examine whether RTAs actually enhance international technology spillovers. They use panel data on patent citations at the USPTO for 114 countries/economies for the period 1991–2007. The focus of their study is on whether the depth of RTAs that is measured by the legal enforceability information on the policy areas in the WTO-X group matters for technology spillovers among member countries/economies of RTAs.¹ They show that the depth of integration actually influences technology spillovers. Interestingly, they find that deeper integration in a broad sense has a greater impact on technology spillovers than do technology-related policy areas. They classify 26 out of 38 policy areas in the WTO-X group into three subsets by utilizing the technique of the factor analysis. Then, they construct a new measure of the nature of deep RTAs by calculating the ratio of the sum of the points of legally enforceable WTO-X policy areas included in each subset that are covered by RTAs to the total points of all legally enforceable WTO-X policy areas covered by the same RTAs. They interpret the first subset as the set of policy areas representing a healthy economic environment in a general sense and the second subset as the set of policy areas representing basic social and economic conditions. The WTO-X policy areas included in these two subsets are not directly related to technology spillovers. On the other hand, the third subset is interpreted as the set of policy areas directly related to competition and technology. Their finding is that the estimated coefficients of the indexes for the first two subsets tend to be larger than those for the third subset.

The analysis in this chapter extends and enriches the study by Jinji et al. (2019a) in several ways. First, as in Jinji et al. (2019a) and Chaps. 5 and 6 of this book, we use patent citations as a proxy of technology spillovers.² We extend the observation period until 2015. Thus, our observation period is 25 years from 1991 to 2015. The eight-year extension of the observation period from Jinji et al. (2019a) is important because more recent RTAs tend to be much deeper. Second, when we estimate the model, we include directional country-pair fixed effects, which are not included in the analysis in Jinji et al. (2019a), as well as time-varying citing and cited countries fixed effects. As we discuss below, the inclusion of country-pair fixed effects is particularly important to address the endogeneity issue (Baier and Bergstrand 2007). Third, we include intra-national citation data in the analysis, which are not included in the estimations of Jinji et al. (2019a). This is essential to measure the effect of RTAs, as argued by Dai et al. (2014). Finally, although Jinji et al. (2019a) restrict the measurement of deep RTAs to the WTO-X policy areas, we include policy areas in

¹ See Chap. 2 for the details of the policy areas in WTO-extra (WTO-X) and WTO-plus (WTO+) groups.

² This approach was pioneered by Jaffe et al. (1993) and has been employed by a number of studies (e.g., Branstetter 2006; Cappelli and Montobbio 2020; Hall et al. 2001; Haruna et al. 2010; Jaffe and Trajtenberg 1999; Jinji et al. 2013, 2015; Li 2014; MacGarvie 2006; Maurseth and Verspagen 2002; Murata et al. 2014; Peri 2005).

both WTO+ and WTO-X groups and employ the classification of the policy areas in terms of the depth and breadth of RTAs proposed by Limão (2016).³

In this chapter, we first estimate the effects of the depth and breadth indexes of RTAs on bilateral patent citations. With regard to the depth of RTAs, we use the indexes in the fields of tariffs, non-tariff barriers (NTBs), the behind-the-border policies (BBPs), and other policies (OPs). On the other hand, as for the breadth of RTAs, we construct indexes for services, technology, investment/capital, labor, and non-economic policies (NEPs) fields. Throughout this chapter, we employ the Poisson pseudo-maximum likelihood (PPML) estimator with time-varying citing country fixed effects, time-varying cited country fixed effects, and citing-cited-pair fixed effects, which is recommended in the gravity literature (Anderson and van Wincoop 2003; Head and Mayer 2014; Santos Silva and Tenreyro 2006, 2011; Yotov et al. 2016).

We next analyze the heterogeneous effects of individual RTAs. In the trade literature, a number of previous studies find the heterogeneous effects of RTAs on trade in goods by the type of agreements (Roy 2010; Vicard 2009) and by the characteristics of country-pairs and particular countries (Baier et al. 2019; Behar and Cirera-i Crivillé 2013; Cheong et al. 2015; Vicard 2011). Although Jinji et al. (2019a) investigate the heterogeneous effects of RTAs on technology spillovers by the type of agreements (i.e., customs union versus free trade agreement) and by the characteristics of country-pairs (i.e., North and South combinations), the heterogeneous effects of individual RTAs on technology spillovers have not been investigated. As major sources of international technology spillovers, we focus on RTAs signed by the United States and European countries, such as the North American Free Trade Agreement (NAFTA), the European Community (EC)/European Union (EU), RTAs with the United States, and FTAs with the EC/EU.

The main findings of this chapter are as follows. First, we find that the estimated coefficient on the RTA dummy is positive and highly significant, which confirms the finding by Jinji et al. (2019a) and even strengthens their finding by showing that the significantly positive effect of the RTA dummy is kept even if directional country-pair fixed effects are included. Second, we find that the coefficients on the depth indexes other than the OP index are positive and highly significant, suggesting that technology spillovers among signatories of RTAs are stronger as RTAs are deeper. However, when each of the depth indexes is estimated together with the RTA dummy, the coefficient on the depth index becomes insignificant, which suggests that the additional effect of including the depth policy areas may be small or even negligible. A possible reason for the insignificant additional effect of the depth policy areas is that since most of the recent RTAs tend to become deeper and deeper, the estimated average effect of the RTA dummy partly captures the impact of the depth policy areas on technology spillovers. The problem of multicollinearity may affect the result.

Third, the estimated coefficients on the breadth indexes are all positive and statistically significant, suggesting that technology spillovers among members of RTAs become stronger as RTAs cover more policy areas with legal enforceability in each of

³ See Chap. 2 for the details of the depth and breadth of RTAs by Limão (2016).

the breadth fields. However, similar to the depth indexes, when the breadth indexes are estimated with the RTA dummy, all of them lose their significance. Therefore, the additional effects of including legally enforceable provisions in services, technology, investment/capital, labor, or NEP fields on cross-border technology spillovers may be small or insignificant. Since some of the specific provisions in these fields actually strengthen regulations, this result implies that the same level of the index in each breadth field may include both the positive and negative effects on technology spillovers.

Finally, with regard to the heterogeneous effects of the RTAs signed by the United States and the EU, we find that the impact of NAFTA on bilateral technology spillovers is particularly strong. By contrast, the impacts of the EU and EU enlargement on technology spillovers are weak or not positive. On the other hand, both the RTAs with the United States and the FTAs with the EU enhance technology spillovers. Thus, the results suggest that signing RTAs with technologically advanced countries, such as the United States and major European countries, is effective in stimulating cross-border technology spillovers.

The remainder of the chapter is organized as follows. In Sect. 7.2, we explain the empirical framework. In Sect. 7.3, we describe the data employed in our empirical analysis. In Sect. 7.4, we present our empirical results. Section 7.5 concludes the chapter.

7.2 Empirical Framework

In this section, we explain our empirical framework to examine the effects of deep RTAs on international technology spillovers.

7.2.1 *The Depth and Breadth Indexes*

We first explain how we measure the contents of deep RTAs. As explained in Chap. 2, Horn et al. (2010) identify 52 policy areas covered by RTAs and classify them into two groups: WTO-plus (WTO+) and WTO-extra (WTO-X) (See Table 2.1 in Chap. 2 for the details of the WTO+ and WTO-X policy areas). Then, Limão (2016) proposes recategorizing the WTO+ and WTO-X policy areas from the viewpoints of the depth and breadth of RTAs. The depth of RTAs is measured by four fields: (a) import tariffs, (b) NTBs, (c) BBPs, and (d) OPs. On the other hand, the breadth of RTAs is measured by five fields: (a) services, (b) technology, (c) investment/capital, (d) labor, and (e) NEPs. Which policy areas are classified into each field of the depth and breadth measures is shown in Table 2.2 in Chap. 2.

For each field of the depth measure, we construct the following index:

$$RTA_Depth_d_index_{ijt} = \frac{\sum_{p \in \Theta^d} Max_LE_{ijt}^p}{2K^d}, \quad (7.1)$$

where $Depth_d \in \{Tariff, NTB, BBP, OP\}$ indicates the fields of the depth measure, Θ^d is the set of policy areas that consist of the field $d \in \{Tariff, NTB, BBP, OP\}$, $Max_LE_{ijt}^p \in \{0, 1, 2\}$ is the maximum point of the LE index of policy area p in all RTAs of which countries i and j are members in year t if they sign any common RTAs, and K^d is the number of policy areas in field d . Note that $2K^d$ in the denominator of Eq. (7.1) is the total points of the LE index of policy areas in field d if all LE indexes are equal to two in field d . Thus, $RTA_Depth_d_index_{ijt}$ takes the value between zero and one.

Similar to the depth measure, we construct the following index for each field of the breadth measure:

$$RTA_Breadth_c_index_{ijt} = \frac{\sum_{p \in \Theta^c} Max_LE_{ijt}^p}{2K^c}, \quad (7.2)$$

where $Breadth_c \in \{GATS, Tech, Cap, Lab, non-EP\}$ indicates the fields of the breadth measure, Θ^c is the set of policy areas that consist of the field $c \in \{GATS, Tech, Cap, Lab, non-EP\}$, $Max_LE_{ijt}^p \in \{0, 1, 2\}$ is the maximum point of the LE index of policy area p in all RTAs of which countries i and j are members in year t if they sign any common RTAs, and K^c is the number of policy areas in field c .

7.2.2 RTA Dummies

Let us next explain our RTA dummies. In addition to the usual RTA dummy, we use various dummies to capture the heterogeneous effects of individual RTAs by decomposing the RTA dummy.

First of all, RTA_dummy_{ijt} is a dummy variable that takes the value of unity if countries i and j both belong to the same RTA in t and zero otherwise. Next, we decompose the RTA_dummy_{ijt} in two ways. The first decomposition is to take into account the NAFTA and the EC/EU. That is, we set $NAFTA_{ijt}$, which is a dummy variable that takes the value of unity if countries i and j both belong to the NAFTA in t and zero otherwise. Similarly, EU_{ijt} is a dummy variable that takes the value of unity if they both belong to the EC/EU in t and zero otherwise. Furthermore, we set $Other_RTA_{ijt}$, which is a dummy variable that takes the value of unity if they both belong to the same RTA other than the NAFTA and the EC/EU in t and zero otherwise.

Next, our second decomposition of the RTA dummy is to take into account RTAs signed by the United States other than the NAFTA and EU enlargement from 1995. We construct $RTA_with_US_{ijt}$, which is a dummy variable that takes the value of unity if either of countries i and j is the United States and the two countries belong

to the same RTA other than the NAFTA in t and zero otherwise. $EU_Enlarge_{ijt}$ is a dummy variable that takes the value of unity if at least one of the two countries (i and j) becomes a member of the EU in or after 1995 and both they are the members of the EU in year t and zero otherwise. Moreover, $FTA_with_EU_{ijt}$ is a dummy variable that takes the value of unity if either of countries i and j is a member of the EC/EU in t and the other country is not a member of the EC/EU in t but countries i and j belong to the same FTA in t and zero otherwise. Finally, $non_US_EU_RTA_{ijt}$ is a dummy variable that takes the value of unity if they belong to the same RTA in t and $NAFTA_{ijt} = EU_{ijt} = RTA_with_US_{ijt} = EU_Enlarge_{ijt} = FTA_with_EU_{ijt} = 0$ holds for them in t and zero otherwise.⁴

In addition, we use the GATT/WTO dummy. That is, WTO_dummy_{ijt} is a dummy variable that takes the value of unity if both of countries i and j are GATT/WTO members in t and zero otherwise.

7.2.3 Empirical Model and Strategy

We next specify a model of knowledge flows between countries and discuss our empirical strategy to estimate the model.

We first measure technology spillovers from country j to country i at time t by extending the framework proposed by Jaffe et al. (1993), Jaffe and Trajtenberg (1999), and Peri (2005). Let Φ_{ijt} be the actual flow of knowledge from country j to country i at time t in terms of the actual effects on the research output in country i . Then, we assume that Φ_{ijt} depends on both the knowledge stock in country j at t , K_{jt} , and the research ability of firms in country i at t , Q_{it} , as follows:

$$\Phi_{ijt} = (Q_{it})^{\alpha_1} (\tilde{\phi}_{ijt} K_{jt})^{\alpha_2}, \quad (7.3)$$

where $\tilde{\phi}_{ijt} \in [0, 1]$ is the degree of accessibility for firms in country i to the knowledge stock in country j at t . Thus, $(\tilde{\phi}_{ijt} K_{jt})$ is the effective unit of country j 's knowledge stock from the perspective of firms in country i . Parameters α_1 and α_2 are both positive. For notational simplicity, we relabel $\tilde{\phi}_{ijt}$ as $\phi_{ijt} \equiv (\tilde{\phi}_{ijt})^{\alpha_2}$.

The degree of accessibility for firms in country i to the knowledge stock in country j at t , ϕ_{ijt} , depends on the *economic distance* between countries i and j , which is affected by not only bilateral geographical distance but also other potential *resistance factors* (Peri 2005, p. 310). The resistance factors include both time-invariant and time-varying country-pair specific characteristics. The time-invariant country-pair specific characteristics include bilateral geographical distance, the use of a common

⁴ Note that in the second decomposition we do not set a dummy variable for the country-pairs of which both countries were the members of the EC/EU before 1995. However, with the use of country-pair fixed effects in our estimations, this omission of the dummy variable for the old members of the EC/EU does not affect the estimations, because this dummy always takes the value of unity during our observation period.

language, and so on. On the other hand, the time-varying country-pair specific characteristics, which affect the economic distance between two countries, are typically represented by the membership of the same RTA and that of GATT/WTO.

Let $\mathbf{x}_{ijt}$ be a set of bilateral country characteristics. Then, we have

$$\begin{aligned}\phi_{ijt} &= \phi(\mathbf{x}_{ijt}) \\ &= e^{\xi_{ij}} e^{\gamma_1(RTA\ dummies_{ijt})} e^{\gamma_2(DRTA_index_{ijt})} \\ &\quad \times e^{\gamma_3(WTO\ dummy_{ijt})},\end{aligned}\tag{7.4}$$

where ξ_{ij} denotes the time-invariant country-pair specific characteristics and $DRTA_index_{ijt}$ denotes various indexes of the depth and breadth of RTAs.

Since Φ_{ijt} , Q_{it} , and K_{jt} in Eq. (7.3) are not directly observable, we need to use some proxies for those variables in our analysis. We use C_{ijt} , the number of patent citations made by the patents of country i to those of country j at time t , as a proxy for Φ_{ijt} . Moreover, following the gravity literature (Head and Mayer 2014; Yotov et al. 2016), we capture Q_{it} by the time-varying citing country fixed effects, $\tilde{\mu}_{it}$, and K_{jt} by the time-varying cited country fixed effects, $\tilde{v}_{jt}$. According to Peri (2005), we assume the following relationship between C_{ijt} and Φ_{ijt} :

$$C_{ijt} = \tilde{\lambda}_{ij} \Phi_{ijt} e^{\epsilon_{ijt}},\tag{7.5}$$

where $\tilde{\lambda}_{ij}$ denotes the time-invariant individual effect associated with patent citations between the two countries and $e^{\epsilon_{ijt}}$ is an error term with zero-mean distribution.

Substitute Eqs. (7.3) and (7.4), $\tilde{\mu}_{it}$ and $\tilde{v}_{jt}$ into Eq. (7.5) to obtain

$$\begin{aligned}C_{ijt} &= \tilde{\lambda}_{ij} (\tilde{\mu}_{it})^{\alpha_1} (\tilde{v}_{jt})^{\alpha_2} e^{\xi_{ij}} e^{\gamma_1(RTA\ dummies_{ijt})} e^{\gamma_2(DRTA_index_{ijt})} \\ &\quad \times e^{\gamma_3(WTO\ dummy_{ijt})} e^{\epsilon_{ijt}}.\end{aligned}\tag{7.6}$$

This equation is quite similar to the standard gravity equation that specifies the relationship between the volume of bilateral trade and the market sizes of the two countries with bilateral geographical distance (Anderson and van Wincoop 2003; Head and Mayer 2014; Yotov et al. 2016). By redefining the fixed effects variables, Eq. (7.6) can be rewritten as

$$\begin{aligned}C_{ijt} &= \exp\left(\gamma_1 RTA\ dummies_{ijt} + \gamma_2 DRTA_index_{ijt} + \gamma_3 WTO\ dummy_{ijt}\right. \\ &\quad \left.+ \zeta_{ij} + \mu_{it} + \nu_{jt} + \epsilon_{ijt}\right).\end{aligned}\tag{7.7}$$

Equation (7.7) is our estimation equation for the analysis in Sect. 7.4. In this equation, we use the RTA dummy and the decomposed RTA dummies that we construct in Sect. 7.2.2. We also use the depth and breadth indexes that we construct in Sect. 7.2.1 for $DRTA_index_{ijt}$. In the estimations, we make use of one-year lagged variables for $RTA\ dummies_{ijt}$, $DRTA_index_{ijt}$, and $WTO\ dummy_{ijt}$.

In the estimations, we employ the PPML estimator with time-varying citing country fixed effects, time-varying cited country fixed effects, and directional country-pair fixed effects, recommended in the gravity literature (Anderson and van Wincoop 2003; Head and Mayer 2014; Santos Silva and Tenreyro 2006, 2011; Yotov et al. 2016). As is popularly argued in the gravity literature, the use of PPML estimator with time-varying country fixed effects can address the issues of many observations with zero value for the dependent variable and unobservable multilateral resistance terms. Now there is one important issue that we should address the potential endogeneity of RTAs. Possible sources of such endogeneity are the existence of an omitted variable bias and reverse causality (Baier and Bergstrand 2007). Baier and Bergstrand (2007) and Yotov et al. (2016) recommend the use of country-pair fixed effects to take “the unobservable linkages between the endogenous trade policy covariate and the error term in gravity regressions” (Yotov et al. 2016, p.21) into account. We follow their recommendation and include citing-cited-country-pair fixed effects in our estimations to address the endogeneity issue.

7.3 Description of the Data

The data on patent citations are taken from the Global 2019 edition of the EPO Worldwide Patent Statistical Database (PATSTAT). We extract the patent statistics of the USPTO from the PATSTAT.⁵ This dataset includes information on the application date, the country name of the assignee, the main US patent class, and citations made and received for each patent. We use patent citation data from 1991 to 2015 for our analysis.

The sample includes all countries and economies that are included in the USPTO data during the observation period. Our sample covers 243 countries and economies, which are listed in Table 7.1. We then construct a panel of 11,667 pairs of the citing and cited countries/economies for 25 years from 1991 to 2015.

Data on RTAs are taken from the database provided by Mario Larch (Egger and Larch 2008),⁶ and data on the content of RTAs are taken from the World Bank’s website.⁷

Table 7.2 shows the descriptive statistics of the variables.

7.4 Empirical Results

In this section, we report our estimation results.

⁵ We also extract the patent statistics of the EPO and use them for a robustness check.

⁶ www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html.

⁷ This dataset was originally provided by Horn et al. (2010) and extended by Hofmann et al. (2019) (datacatalog.worldbank.org/dataset/content-deep-trade-agreements).

Table 7.1 Sampled countries/economies

No.	Country/Economy	No.	Country/Economy	No.	Country/Economy	No.	Country/Economy
1	Afghanistan	64	Dominican Rep.	126	Liberia	187	Saint Kitts & Nevis
2	Aland Islands	65	Ecuador	127	Libya	188	Saint Lucia
3	Albania	66	Egypt	128	Liechtenstein	189	Saint Pierre and Miquelon
4	Algeria	67	El Salvador	129	Lithuania	190	Saint Vincent & the Grenadines
5	American Samoa	68	Equatorial Guinea	130	Luxembourg		
6	Andorra	69	Eritrea	131	Macao	191	Samoa
7	Angola	70	Estonia	132	Madagascar	192	San Marino
8	Anguilla	71	Eswatini	133	Malawi	193	Sao Tome & Principe
9	Antarctica	72	Ethiopia	134	Malaysia	194	Saudi Arabia
10	Antigua and Barbuda	73	Falkland Islands	135	Maldives	195	Senegal
11	Argentina	74	Faroe Islands	136	Mali	196	Serbia & Montenegro
12	Armenia	75	Fiji	137	Malta	197	Seychelles
13	Aruba	76	Finland	138	Marshall Islands	198	Sierra Leone
14	Australia	77	France	139	Martinique	199	Singapore
15	Austria	78	French Guiana	140	Mauritania	200	Sint Maarten
16	Azerbaijan	79	French Polynesia	141	Mauritius	201	Slovakia
17	Bahamas	80	French Southern Territories	142	Mexico	202	Slovenia
18	Bahrain	81	Gabon	143	Micronesia	203	Solomon Islands
19	Bangladesh	82	Gambia	144	Moldova	204	Somalia
20	Barbados	83	Georgia	145	Monaco	205	South Africa
21	Belarus	84	Germany	146	Mongolia	206	Spain
22	Belgium	85	Ghana	147	Montenegro	207	Sri Lanka
23	Belize	86	Gibraltar	148	Montserrat	208	Sudan (the)
24	Benin	87	Greece	149	Morocco	209	Suriname
25	Bermuda	88	Greenland	150	Mozambique	210	Svalbard & Jan Mayen
26	Bhutan	89	Grenada	151	Myanmar		
27	Bolivia	90	Guadeloupe	152	Namibia	211	Sweden
28	Bonaire, Sint Eustatius & Saba	91	Guam	153	Nauru	212	Switzerland
29	Bosnia and Herzegovina	92	Guatemala	154	Nepal	213	Syrian Arab Rep.
30	Botswana	93	Guernsey	155	Netherlands	214	Taiwan
31	Bouvet Island	94	Guinea	156	Netherlands antilles	215	Tajikistan
32	Brazil	95	Guyana	157	New Caledonia	216	Tanzania
33	British Indian Ocean Territory	96	Haiti	158	New Zealand	217	Thailand
34	Brunei Darussalam	97	Heard Islands & McDonald Islands	159	Nicaragua	218	Togo
				160	Niger (the)	219	Tokelau
35	Bulgaria	98	Holy See	161	Nigeria	220	Tonga
36	Burkina Faso	99	Honduras	162	Niue	221	Trinidad & Tobago
37	Burundi	100	Hong Kong	163	Norfolk Island	222	Tunisia
38	Cabo Verde	101	Hungary	164	Northern Mariana Islands	223	Turkey
39	Cambodia	102	Iceland	165	Norway	224	Turkmenistan
40	Cameroon	103	India	166	Oman	225	Turks & Caicos

(continued)

Table 7.1 (continued)

No.	Country/Economy	No.	Country/Economy	No.	Country/Economy	No.	Country/Economy
41	Canada	104	Indonesia	167	Pakistan		Islands
42	Cayman Islands	105	Iran	168	Palau	226	Tuvalu
43	Central African Republic	106	Iraq	169	Palestine, State of	227	Uganda
		107	Ireland	170	Panama	228	Ukraine
44	Chad	108	Isle of Man	171	Papua New Guinea	229	UAE
45	Chile	109	Israel	172	Paraguay	230	United Kingdom
46	China	110	Italy	173	Peru	231	US Minor
47	Christmas Island	111	Jamaica	174	Philippines		Outlying Islands
48	Cocos Islands	112	Japan	175	Pitcairn	232	United States
49	Colombia	113	Jersey	176	Poland	233	Uruguay
51	Congo	114	Jordan	177	Portugal	234	Uzbekistan
52	Congo, Dem. Rep.	115	Kazakhstan	178	Puerto Rico	235	Vanuatu
53	Cook Islands	116	Kenya	179	Qatar	236	Venezuela
54	Costa Rica	117	Kiribati	180	Rep. of North Macedonia	237	Viet Nam
55	Cote d'Ivoire	118	Korea, Dem. People's Rep.			238	Virgin Islands, British
56	Croatia			181	Reunion	239	Virgin Islands, US
57	Cuba	119	Korea, Rep. of	182	Romania	240	Wallis and Futuna
58	Curacao	120	Kuwait	183	Russian Federation	241	Yemen
59	Cyprus	121	Kyrgyzstan	184	Rwanda	242	Zambia
60	Czechia	122	Laos	185	Saint Barthelemy	243	Zimbabwe
61	Denmark	123	Latvia	186	Saint Helena, Ascension & Tristan da Cunha		
62	Djibouti	124	Lebanon				
63	Dominica	125	Lesotho				

7.4.1 The Depth of RTAs

First, we estimate the impact of the depth of RTAs on bilateral technology spillovers. The results obtained are reported in Table 7.3. Column (1) shows that the estimated coefficient on the RTA dummy is positive and highly significant. This result confirms the finding by Jinji et al. (2019a) and strengthens their finding by showing that the significantly positive effect of the RTA dummy remains even when directional country-pair fixed effects are included. Signing an RTA increases bilateral citation of patents by 4.8% on average.⁸

The effects of the four depth indexes are shown in columns (2)–(5). The coefficients on the first three depth indexes are positive and highly significant. The estimated coefficient on *RTA_Tariff_index* is 0.042. Since this index consists of two policy areas with four points in total, an increase in one policy area from zero points to two points (i.e., a change from no legal enforceability to legally enforceable

⁸ $(e^{0.047} - 1) \times 100 \approx 4.8$.

Table 7.2 Descriptive statistics

Variable	No. of Obs	Mean	Std. Dev.	Min	Max
C_{ijt}	291,675	527.023	28134.360	0	4,677,583
$RTA_dummy_{ij,t-1}$	291,675	0.206	0.405	0	1
$RTA_Tariff_index_{ij,t-1}$	291,675	0.121	0.325	0	1
$RTA_NTB_index_{ij,t-1}$	291,675	0.095	0.272	0	1
$RTA_BBP_index_{ij,t-1}$	291,675	0.073	0.220	0	1
$RTA_OP_index_{ij,t-1}$	291,675	0.035	0.150	0	1
$RTA_GATS_index_{ij,t-1}$	291,675	0.073	0.261	0	1
$RTA_Tech_index_{ij,t-1}$	291,675	0.045	0.147	0	0.667
$RTA_Cap_index_{ij,t-1}$	291,675	0.068	0.225	0	1
$RTA_Lab_index_{ij,t-1}$	291,675	0.049	0.194	0	1
$RTA_nonEP_index_{ij,t-1}$	291,675	0.022	0.095	0	0.556
$WTO_dummy_{ij,t-1}$	291,675	0.567	0.500	0	1
$NAFTA_{ij,t-1}$	291,675	0.0004	0.021	0	1
$EU_{ij,t-1}$	291,675	0.035	0.185	0	1
$RTA_with_US_{ij,t-1}$	291,675	0.001	0.032	0	1
$EU_Enlarge_{ij,t-1}$	291,675	0.005	0.070	0	1
$FTA_with_EU_{ij,t-1}$	291,675	0.051	0.220	0	1
$Other_RTA_{ij,t-1}$	291,675	0.172	0.378	0	1
$non_US_EU_RTA_{ij,t-1}$	291,675	0.151	0.358	0	1

policy area) raises bilateral citation of patents by 2.1% on average.⁹ Similarly, the estimated coefficients of the RTA_NTB_index and the RTA_BBP_index are 0.059 and 0.066, where RTA_NTB_index and RTA_BBP_index consist of five policy areas and six policy areas, respectively. Thus, an increase in one policy area from zero points to two points raises bilateral citation of patents by 1.0% for the NTB index and 1.4% for the BBP index, respectively.¹⁰ Only the estimated coefficient on the RTA_OP_index is insignificant.

Columns (6) and (8) show the results on estimations when the RTA dummy and each of RTA_NTB_index , RTA_BBP_index , or RTA_OP_index are jointly used as explanatory variables. The results may suffer from the problem of multicollinearity as the correlations among the RTA dummy and the depth indexes are high. In column (6), both the RTA dummy and the RTA_NTB_index become insignificant, whereas in columns (7) and (8) the coefficient on the RTA dummy is positive and significant but that on the RTA_BBP_index or the RTA_OP_index is insignificant. These results imply that the additional effect of including the depth policy areas in the fields of NTB, BBP, and OP may be small or even insignificant. A possible reason for the insignificant additional effect of the depth policy areas is

⁹ $(e^{0.042} - 1) \times (1/4) \times 2 \times 100 \approx 2.1$.

¹⁰ $(e^{0.059} - 1) \times (1/10) \times 2 \times 100 \approx 1.0$ and $(e^{0.066} - 1) \times (1/12) \times 2 \times 100 \approx 1.4$.

Table 7.3 The impact of the depth indexes on technology spillovers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>RTA dummy_{ijt-1}</i>	0.047*** (0.011)					0.021 (0.029)	0.044** (0.022)	0.049*** (0.012)
<i>RTA_Tariff_index_{ijt-1}</i>		0.042*** (0.011)						
<i>RTA_NTB_index_{ijt-1}</i>			0.059*** (0.013)			0.036 (0.037)		
<i>RTA_BBP_index_{ijt-1}</i>				0.066*** (0.020)			0.006 (0.039)	
<i>RTA_OP_index_{ijt-1}</i>					0.043 (0.072)			-0.029 (0.065)
<i>WTO dummy_{ijt-1}</i>	0.263** (0.108)	0.264** (0.108)	0.264** (0.108)	0.264** (0.108)	0.263** (0.108)	0.264** (0.108)	0.263** (0.108)	0.263** (0.108)
Citing country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cited country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Directional country-pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	236,953	236,953	236,953	236,953	236,953	236,953	236,953	236,953

Notes: (a) Estimations were implemented using Stata command `ppmlhdfc`

(b) ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively

(c) Standard errors clustered by country-pair are in parentheses

(d) The regressions include a constant term

that most of the RTAs that have recently been signed tend to be increasingly deeper. Thus, we can conclude that the estimated average effect of the RTA dummy partly captures the impact of the depth policy areas on technology spillovers.

By contrast, the estimated coefficient on the *WTO* dummy is positive and highly significant in all columns, and its magnitude is large. If both countries are members of GATT/WTO, then bilateral citations of patents are on average 30.2% higher than those in other types of country-pairs.¹¹

7.4.2 The Breadth of RTAs

We next estimate the impact of the breadth of RTAs on bilateral technology spillovers. Estimated results are shown in Table 7.4. Columns (1)–(5) indicate the individual effect of the five breadth indexes: *RTA_GATS_index*, *RTA_Tech_index*, *RTA_Cap_index*, *RTA_Lab_index*, and *RTA_nonEP_index*. The estimated coefficients are positive and statistically significant for all of them. For example, the estimated coefficient on the *RTA_GATS_index* is 0.045 and the GATS field consists of just one policy area, so that an increase in this index from zero points to two points raises cross-border citations of patents by 4.6%.¹² Since the coefficient on the *RTA_Tech_index* is 0.084 and the technology field consists of six policy areas, an increase in one technology-related policy area from zero points to two points raises bilateral citations of patents by 1.5%.¹³ Similarly, since the coefficient on the *RTA_Cap_index* is 0.045 and the investment/capital field is comprised of three policy areas, an increase in one investment/capital policy area from zero points to two points raises bilateral citations of patents by 1.5%.¹⁴ On the other hand, the impact of the labor-related policy fields becomes much larger. The estimated coefficient on the *RTA_Lab_index* is 0.133. The labor field consists of four policy areas, so that a rise in one labor-related policy area from zero point to two points causes bilateral citations of patents by 3.6% to increase.¹⁵ The larger impact of the RTAs with legally enforceable labor-related policy areas than those with technology and investment/capital policy areas implies that the movement of workers across countries stimulated by signing RTAs is an important channel of technology spillovers. In column (5), the coefficient on the *RTA_nonEP_index* is 0.189, where the NEP field consists of nine policy areas, so an increase in one NEP policy area from zero point to two points raises bilateral citations of patents by 2.3%.¹⁶

Compared with the results above, the results presented in columns (6)–(10) indicate that all of them lose their statistical significance when the breadth indexes are

¹¹ $(e^{0.264} - 1) \times 100 \approx 30.2$.

¹² $(e^{0.045} - 1) \times (1/2) \times 2 \times 100 \approx 4.6$.

¹³ $(e^{0.084} - 1) \times (1/12) \times 2 \times 100 \approx 1.5$.

¹⁴ $(e^{0.045} - 1) \times (1/6) \times 2 \times 100 \approx 1.5$.

¹⁵ $(e^{0.133} - 1) \times (1/8) \times 2 \times 100 \approx 3.6$.

¹⁶ $(e^{0.189} - 1) \times (1/18) \times 2 \times 100 \approx 2.3$.

Table 7.4 The impact of the breadth indexes on technology spillovers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>RTA dummy</i> _{<i>ij,t-1</i>}						0.032 (0.025)	0.060*** (0.022)	0.051* (0.028)	0.041*** (0.011)	0.042*** (0.016)
<i>RTA_GATS_index</i> _{<i>ij,t-1</i>}	0.045*** (0.011)					0.016 (0.027)				
<i>RTA_Tech_index</i> _{<i>ij,t-1</i>}		0.084** (0.036)					-0.039 (0.062)			
<i>RTA_Cap_index</i> _{<i>ij,t-1</i>}			0.045*** (0.012)					-0.004 (0.029)		
<i>RTA_Lab_index</i> _{<i>ij,t-1</i>}				0.133*** (0.047)					0.044 (0.046)	
<i>RTA_nonEP_index</i> _{<i>ij,t-1</i>}					0.189*** (0.064)					0.039 (0.085)
<i>WTO dummy</i> _{<i>ij,t-1</i>}	0.264** (0.108)	0.264** (0.108)	0.264** (0.108)	0.263** (0.108)	0.263** (0.108)	0.264** (0.108)	0.263** (0.108)	0.263** (0.108)	0.263** (0.108)	0.263** (0.108)
Citing country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cited country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Directional country-pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	236,953	236,953	236,953	236,953	236,953	236,953	236,953	236,953	236,953	236,953

Notes: (a) Estimations were implemented using Stata command `ppmlhdfc`
(b) ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively
(c) Standard errors clustered by country-pair are in parentheses
(d) The regressions include a constant term

estimated with the *RTA* dummy. This means that the additional effect of including legally enforceable policy areas in services, technology, investment/capital, labor, or NEP field on bilateral technology spillovers may be negligible. However, it should be noted that the problem of multicollinearity may distort the estimated coefficients of the breadth indexes. Moreover, the inclusion of legally enforceable policy areas in services, technology, investment/capital, labor, or NEP field does not necessarily increase bilateral citations of patents because some of the policy areas in these fields actually strengthen regulations. The same level of the index in each breadth field may include not only the positive effect but also the negative effect on technology spillovers. Consequently, the positive impact of the breadth index may be weakened.

Note that the estimated coefficient on the *WTO* dummy in Table 7.4 is almost the same as that in Table 7.3.

7.4.3 *Heterogeneous Effects of RTAs by the United States and the EU*

Our next focus is on the heterogeneous effects of the RTAs signed by the United States and the EU. Table 7.5 shows the estimated results. Column (1) shows the effects of the NAFTA and the EU. Interestingly, while the estimated coefficient on the *NAFTA* dummy is positive and highly significant, that of the *EU* dummy is negative and significant. NAFTA increases bilateral citations of patents among Canada, Mexico, and the United States by 28.5% on average.¹⁷ The NAFTA membership is fairly comparable in magnitude to the GATT/WTO membership.

Column (2) reports the effects of RTAs with the United States, EU enlargement, and FTAs with the EU. RTAs with the United States, other than NAFTA, have on average a positive and significant effect on bilateral patent citations. Moreover, although the impact of EU enlargement is insignificant, FTAs with the EU affect positively bilateral patent citations on average. These results suggest that the impact of NAFTA is much larger than that of other RTAs.

7.4.4 *Robustness Check*

The large impact of NAFTA and the small one of the EU on bilateral citations of patents shown in the previous subsection may be due to the use of the USPTO data. In other words, one may suspect that the home bias may cause the heterogeneous effects between NAFTA and the EU.

To check the robustness of the finding in the previous subsection, we employ the EPO data and construct the dataset, so that the same country-pairs are included in both the USPTO and the EPO citations. Then, we estimate the same specifications

¹⁷ $(e^{0.251} - 1) \times 100 \approx 28.5$.

Table 7.5 Heterogeneous effects of RTAs by the United States and the EU

	(1)	(2)
<i>NAFTA</i> _{<i>ij,t-1</i>}	0.251*** (0.090)	0.259*** (0.092)
<i>EU</i> _{<i>ij,t-1</i>}	-0.089* (0.046)	
<i>Other_RT</i> _{<i>ij,t-1</i>}	0.040*** (0.011)	
<i>RTA_with_US</i> _{<i>ij,t-1</i>}		0.054*** (0.011)
<i>EU_Enlarge</i> _{<i>ij,t-1</i>}		0.078 (0.075)
<i>FTA_with_EU</i> _{<i>ij,t-1</i>}		0.093*** (0.023)
<i>non_US_EU_RT</i> _{<i>ij,t-1</i>}		-0.009 (0.025)
<i>WTO dummy</i> _{<i>ij,t-1</i>}	0.263** (0.108)	0.264** (0.108)
Citing country-year FE	Yes	Yes
Cited country-year FE	Yes	Yes
Directional country-pair FE	Yes	Yes
No. of observations	236,953	236,953

Notes: (a) Estimations were implemented using Stata command `ppmlhdfc`

(b) ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels respectively

(c) Standard errors clustered by country-pair are in parentheses

(d) The regressions include a constant term

with those in Table 7.5 for both the USPTO and the EPO citations. The results are reported in Table 7.6. Columns (1) and (2) show the results of the USPTO citations, and columns (3) and (4) show those of the EPO citations.

Comparing the estimated coefficients on the *NAFTA* dummy in columns (1)–(2) and columns (3)–(4), the coefficient is positive in both columns (3)–(4) and significant in column (4), although the magnitude becomes smaller in columns (3)–(4). By contrast, the coefficient on the *EU* dummy is negative and significant in both columns (1) and (3). The estimated coefficient on the EU enlargement dummy is insignificant in both columns (2) and (4). Moreover, whereas the coefficient on the *FTA_with_EU* dummy is positive and significant in column (2), it is negative and insignificant in column (4).

We conclude that the findings in Table 7.5 are not due to the home bias and that these findings are robust.

Table 7.6 Robustness check: USPTO citations versus EPO citations

	(1)	(2)	(3)	(4)
	USPTO	USPTO	EPO	EPO
$NAFTA_{ij,t-1}$	0.251*** (0.090)	0.259*** (0.092)	0.128 (0.114)	0.196* (0.115)
$EU_{ij,t-1}$	-0.094* (0.046)		-0.149*** (0.043)	
$Other_RTA_{ij,t-1}$	0.040*** (0.011)		-0.081*** (0.026)	
$RTA_with_US_{ij,t-1}$		0.054*** (0.011)		-0.010 (0.034)
$EU_Enlarge_{ij,t-1}$		0.078 (0.075)		-0.053 (0.061)
$FTA_with_EU_{ij,t-1}$		0.093*** (0.024)		-0.039 (0.032)
$non_US_EU_RTA_{ij,t-1}$		-0.010 (0.026)		-0.070* (0.036)
$WTO_dummy_{ij,t-1}$	0.269** (0.110)	0.270** (0.110)	0.664*** (0.207)	0.665*** (0.207)
Citing country-year FE	Yes	Yes	Yes	Yes
Cited country-year FE	Yes	Yes	Yes	Yes
Directional country-pair FE	Yes	Yes	Yes	Yes
No. of observations	98,546	98,546	84,578	84,578

Notes: (1) Estimations were implemented using Stata command `ppmlhdfc`

(2) ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively

(3) Standard errors clustered by country-pair are in parentheses

(4) The regressions include a constant term

7.5 Conclusion

In this chapter, we investigated the impact of deep RTAs on international technology spillovers, employing patent citations as a proxy of technology spillovers. We extended and enriched the research by Jinji et al. (2019a) in several ways. The focus of our research is on the impacts of the depth and breadth of RTAs and the heterogeneous effects of individual RTAs on international technology spillovers.

Our main findings are as follows. First, we confirmed the finding by Jinji et al. (2019a) that RTAs significantly enhance international technology spillovers measured by bilateral patent citations. We actually strengthened their finding by deriving the one that the significantly positive coefficient on the RTA dummy is kept even when the model is estimated with directional country-pair fixed effects.

Second, we found that deep RTAs with higher coverage of policy areas in the depth fields such as tariffs, NTBs, and BBPs, and those with higher coverage of

policy areas in the breadth fields such as services, technology, investment/capital, labor, and NEPs at the legally enforceable level have positive effects on international technology spillovers. The additional effects of including the depth or breadth policy areas may be small or even negligible. This may be because the estimated average effect of the RTA dummy partly captures the impact of the depth policy areas on technology spillovers as recent RTAs tend to be increasingly deeper. Moreover, with regard to the breadth fields, the same level of the breadth index may include both the positive and negative effects on technology spillovers, as some policy areas actually strengthen rather than relax regulations. Finally, we found that the NAFTA has a strongly positive impact on international spillovers, whereas the impacts of the EU and EU enlargement on technology spillovers are weak or not positive. However, the RTAs with the United States and the FTAs with the EU both positively affect technology spillovers.

Our empirical results imply that signing deep RTAs with higher coverage of the depth or breadth policy areas is quite effective to enhance bilateral technology spillovers. In addition, signing RTAs with technologically advanced countries, such as the United States and major European countries, is also effective in stimulating cross-border technology spillovers.

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