Kyoto University,
Graduate School of Economics
Research Project Center Discussion Paper Series

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Naoto Jinji
Xingyuan Zhang
Shoji Haruna

Discussion Paper No. E-11-006

Research Project Center
Graduate School of Economics
Kyoto University
Yoshida-Hommachi, Sakyo-ku
Kyoto City, 606-8501, Japan

February 2012

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Naoto Jinji† Xingyuan Zhang‡ Shoji Haruna§

This version: February 1, 2012

Abstract

We investigate empirically how regional integration affects technology spillovers among trade partners. We measure the extent of technology spillovers by using patent citation data from the United States Patent and Trademark Office. Our main finding, from employing the gravity model, is that technology spillovers between trade partners are higher if these countries are signatories to the same regional free trade agreement. This suggests that regional integration has a positive effect on technology spillovers. Another finding is that the GATT/WTO has a positive effect on technology spillovers among member countries.

Keywords: regional trade agreement; technology spillovers; patent citations; gravity model.

JEL classification: F15; O33.

*We thank Akira Ishii and participants of the International Symposium at the Otaru University of Commerce for their helpful comments and suggestions on an earlier version of the paper. Financial support from the Japan Society for the Promotion of Science under the Grant-in-Aid for Scientific Research (B) No. 23330081 is gratefully acknowledged. The authors are solely responsible for any remaining errors.

†Corresponding author. Faculty of Economics, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501, Japan. Phone & fax: +81-75-753-3511. E-mail: jinji #at-mark# econ.kyoto-u.ac.jp.

‡Faculty of Economics, Okayama University, 3-1-1 Tsushima-Naka, Kita-Ku, Okayama 700-8530, Japan.

§Faculty of Economics, Okayama University, 3-1-1 Tsushima-Naka, Kita-Ku, Okayama 700-8530, Japan.

1 Introduction

During the last two decades, the rapid proliferation of regional trade agreements (RTAs) has stimulated the economic analysis of such agreements.[1] The focus of most existing studies is the static effects of RTAs, such as trade creation and trade diversion; the dynamic effects of RTAs are addressed in a relatively small number of studies. However, the enhancement of technology spillovers may be an important effect of RTAs.

Empirical evidence that international trade works as a major channel of international technology spillovers is found in a number of studies (Coe and Helpman, 1995; Xu and Wang, 1999; Acharya and Keller, 2009).[2] Because RTAs increase trade among member countries through the trade creation effect, they may facilitate technology spillovers among trade partners.

In this paper, we attempt to measure technology spillovers by using data on patent citations. The study of technology spillovers based on patent citations was pioneered by Jaffe et al. (1993). Since then, the literature has been growing (e.g., Jaffe and Trajtenberg, 1999; Hall et al., 2001; Maurseth and Verspagen, 2002; MacGarvie, 2006; Branstetter, 2006; Haruna et al., 2010; Jinji et al., 2010, 2011).

An important issue in the literature on technology spillovers based on patent citations is whether technology spillovers are hindered by geographical distance. Evidence of the localization of technology spillovers has been found both in the intranational context (Jaffe et al., 1993; Murata et al., 2010) and in the intraregional or international context (Maurseth and Verspagen, 2002; Paci and Usai, 2009).[3] Maurseth and Verspagen (2002) find that geographical distance has a negative effect on patent citations in 112 European regions; such citations occur more frequently within countries than between regions located in separate countries. They also find that patent citations occur more frequently within regions sharing the same language. Paci and Usai (2009) also examine the influence of geographical distance and spatial proximity on knowledge flows in Europe by extending the sample covered to the aggregate economies of 175 regions in Europe and by incorporating dynamics into the relationships. They confirm previous findings. That is, they find that knowledge flows measured by patent citations decrease as geographical distance increases. Regions sharing borders are more likely mutually to cite respective patents, and citations are more frequent between two regions belonging to the same country.

As discussed above, although the localization of technology spillovers has been well documented, there has been little analysis of the impact of "economic" distance on technology spillovers. In particular, holding the geographical distance between two countries constant, it would be interesting to investigate the extent to which technology spillovers between two countries that are signatories to

[1] In this paper, we use the terms RTAs and free trade agreements (FTAs) interchangeably. A more precise term is preferential trade agreements. To emphasize the aspect of regional integration, we mainly use the term RTAs.

[2] See Keller (2004) for a survey of the literature.

[3] However, evidence of localized knowledge spillovers remains inconclusive. See Thompson and Fox-Kean (2005) and Henderson et al. (2005).

the same RTA differ from those between two countries that are not. To our knowledge, only Peri (2005) has investigated this issue. By using a sample of 147 subnational regions in Western Europe and North America, Peri (2005) estimates a gravity-type equation to examine the effect of several resistance factors on patent citations. He finds that any borders (regional, national, or linguistic) have a significantly negative effect on technology spillovers. By contrast, the effect of trade blocs on technology spillovers is insignificant. Thus, his result suggests that, unlike geographical distance and regional and national borders, trade-bloc borders do not hinder technology spillovers.

The main purpose of this paper is to examine whether RTAs enhance technology spillovers among RTA member countries. As explained above, we follow the literature on patent citations to measure technology spillovers. We apply a version of the gravity model proposed by Rose (2004) to analyze technology spillovers. We include a dummy variable that indicates membership of the same RTA among trading partners. We also include in our gravity model dummies for membership of the GATT/WTO as well as familiar control variables.

We estimate a gravity model for technology spillovers by using a negative binomial model, which represents the standard approach to estimation when one has count data on the dependent variable (Cameron and Trivedi, 1998). Our main finding is that RTAs have a positive and significant effect on technology spillovers, as measured by patent citations between trade partners. This finding is quite different from Peri's (2005). The significantly positive effect of RTAs on technology spillovers remains even when we exclude the US from the sample. We also check the robustness of our results by using a zero-inflated negative binomial (ZINB) model. The estimation results from this model indicate that most of the control variables in the gravity model, such as distance and land borders, have significant coefficients with the expected signs. A secondary finding is that the GATT/WTO enhances technology spillovers among member countries but hampers technology spillovers between member and nonmember countries.

The rest of the paper is organized as follows. In Section 2, we review the literature on the economic effects of regional integration. In Section 3, we explain our approach to measuring technology spillovers by using patent citation data. In Section 4, we explain the empirical framework. In Section 5, we describe the data employed in our empirical analysis. In Section 6, we present our empirical results. Section 7 concludes the paper.

2 The Economic Effects of Regional Integration: Literature Review

In this section, we briefly review the literature on the economic effects of RTAs.[4] The classic work by Viner (1950) demonstrates that the welfare effects of RTAs based on static analysis are generally ambiguous. He introduced the concepts of *trade creation* and *trade diversion*.[5] Although these terms are subject to several shortcomings, "trade creation and trade diversion have remained central to policy debates" on RTAs because "economists have found these terms to be highly effective tools for focusing policy makers' attention on the ambiguous welfare effects" of RTAs (Panagariya, 2000: 293).[6]

The many estimates of the trade creation and trade diversion effects of RTAs include those of Clausing (2001), Fukao et al. (2003), Trefler (2004), and Romalis (2007).[7] If countries in RTAs are large, then RTAs can induce terms-of-trade effects (Baldwin and Venables, 1995; Panagariya, 2000). Chang and Winters (2002) estimate the terms-of-trade gains of Mercosur, a customs union between Argentina, Brazil, Paraguay, and Uruguay. Moreover, the procompetitive effects of regional trade liberalization are important for industries exhibiting economies of scale and facing imperfect competition (Ethier and Horn, 1984; Venables, 1987; Haaland and Wooton, 1992).

The many analyses of the welfare effects of RTAs using computable general equilibrium (CGE) models include those of Brown et al. (1992, 2003), Cox and Harris (1992), Philippidis and Snajuán (2007), Roland-Holst et al. (1994), and Sobarzo (1992).[8] These authors provide predictions of the changes in trade, prices, and welfare attributable to RTAs by incorporating complex interactions of various effects in the general equilibrium framework. In many cases, CGE models incorporate increasing returns and imperfect competition (see, e.g., Brown et al., 1992, 2003; Cox and Harris, 1992; Roland-Holst et al., 1994; Sobarzo, 1992).

More recently, the dynamic effects of RTAs, such as technology adoption and technology diffusion, have attracted much attention. Ben-David (1993) examines the issue of income convergence among European countries and finds significant convergence as economic integration proceeds. However, he

[4] For a survey of the literature, see, e.g., Baldwin and Venables (1995), Bhagwati and Panagariya (1996), Panagariya (2000), and Krishna (2005).

[5] "The former is the substitution in the importing country of a lower cost source of supply within the area for a more costly source and is, therefore, beneficial to the member countries and the world as a whole. In contrast, trade diversion is the substitution of a more costly source of supply within the area for a less costly source outside the area" (Lloyd and MacLaren, 2004: 446).

[6] Detailed discussions of trade creation and trade diversion are provided by Panagariya (2000) and Baldwin and Wyplosz (2009, Chapter 5). Baldwin and Wyplosz (2009: 171) argue that "these terms have become quite standard, so much so that one really cannot talk about preferential liberalization without mentioning them".

[7] Using plant- and industry-level data for Canada and the US, Trefler (2004) estimates the effects of the Canada–US FTA on productivity and employment.

[8] Baldwin and Venables (1995) and Lloyd and MacLaren (2004) provide surveys of empirical studies of the effects of RTAs based on CGE models.

does not specify the factors that induce convergence. Ederington and McCalman (2008) analyze a dynamic model of endogenous firm heterogeneity, in which RTAs affect the adoption rates of new technologies across firms. Bustos (2011) estimates the effects of Mercosur on Argentinean firms' technology adoption. She finds that Brazil's tariff reduction has induced statistically significant increases in technology spending and the innovation (both process and product) indexes of Argentinean firms. Schiff and Wang (2003) estimate the effects of the North American Free Trade Agreement (NAFTA) on total factor productivity (TFP) in Mexico through its impact on trade-related technology transfers from OECD countries, as measured by the trade-related foreign R&D stock. They find that Mexico's trade with its NAFTA partners (Canada and the US) has a statistically significant effect on Mexico's TFP, whereas trade with other OECD countries does not. Their simulation results indicate that NAFTA membership has led to a permanent increase in the TFP of Mexican manufacturing industry of 5.6%–7.5%, which implies a GDP increase of 1.2%–1.6%. Using a CGE model, Das and Andriamananjara (2006) analyze the welfare effects of FTAs in the Americas by incorporating technology spillovers. They compare a 'hub-and-spokes' (HAS)-type FTA with a more comprehensive regional FTA. In the HAS-type FTA they consider, Chile becomes a hub by forming a bilateral FTA with the US and an FTA with Mercosur. The comprehensive regional FTA they consider is the Free Trade Area of the Americas (FTAA). They find evidence of exogenous TFP improvement in high-technology sectors in the US. They also find that technology embodied in intermediate inputs spills over both intranationally and internationally. As expected, according to their simulation, the hub (Chile) gains from the formation of HAS-type FTAs. Whereas moving from a HAS-type FTA to a more comprehensive regional FTA lowers the welfare gain for the hub, it benefits the laggard spoke (Mercosur). The flow of technological innovation reinforces the impact of FTA formation.

3 Technology Spillovers and Patent Citations

The impact of RTAs on international technology spillovers is the main issue addressed in this paper. However, it is not easy to measure technology spillovers.[9] One approach pioneered by Jaffe et al. (1993) is to utilize patent citation data as a proxy for spillovers of technological knowledge.[10] The granting of a patent is "a legal statement that the idea embodied in the patent represents a novel and useful contribution over and above the previous state of knowledge" (Jaffe et al., 1993: 580). Patent citations serve "the legal function of delimiting the scope of the property right conveyed by the patent" (Jaffe et al., 1993: 580). Therefore, "a citation of Patent X by Patent Y means that X represents a piece of previously existing knowledge upon which Y builds" (Jaffe et al., 1993: 580). In

[9] The most popular approach in the literature is to examine the correlation between the TFP of domestic firms and the R&D of foreign firms. See Keller (2004) for a survey of the literature.

[10] There is a growing empirical literature on the study of international technological spillovers based on patent citations (e.g., Jaffe and Trajtenberg, 1999; MacGarvie, 2006; Haruna et al., 2010; Jinji et al., 2010, 2011).

the process of patent application, the applicant is required to provide all references that may affect the patentability of the invention. In the US, the applicant has a legal duty to list the patents that he/she cites on the front page of the application document. Examiners also identify the references that they consider relevant.

Compared with other approaches (such as analyzing the effects on TFP), the advantage of using patent citations is that it is a direct measure of technology spillovers (Hall et al., 2001). However, patent citation is a crude and noisy measure of knowledge flow, because not all inventions are patented, and not all knowledge flows can be captured by patent citations (Jaffe et al., 1993). The range of technology spillovers that can be captured by patent citations is limited to "the process by which one inventor learns from the research outcomes of others' research projects and is able to enhance her own research productivity with this knowledge without fully compensating the other inventors for the value of this learning" (Branstetter, 2006: 327–328).

4 Empirical Framework

To estimate the effects of FTAs on international technology spillovers, we employ the gravity model, which is widely used to explain bilateral trade. Following Jaffe et al. (1993), Jaffe and Trajtenberg (1999) and other researchers, we use patent citation data as a proxy for technology spillovers. Peri (2005) attempts to examine the effects of various regional borders on technology spillovers by employing a gravity-type model in which patent citation is the dependent variable. Our approach is similar to Peri's (2005). We modify the gravity model proposed by Rose (2004, 2005). Our modified version of the gravity equation is given by:

$$\begin{aligned} C_{ijt} = {} & \beta_0 + \beta_1 \ln(P_{it} \times P_{jt}) + \beta_2 Border_{ij} + \beta_3 LDist_{ij} + \beta_4 ComLang_{ij} + \beta_5 ComCol_{ij} \\ & + \beta_6 Colony_{ij} + \gamma_1 Onein_{ijt} + \gamma_2 Bothin_{ijt} + \gamma_3 Regional_{ijt} + \gamma_4 GSP_{ijt} + \varepsilon_{ijt}, \end{aligned} \tag{1}$$

where i and j denote trading partners, t denotes time, and the variables are defined as follows.

- C_{ijt} denotes the number of US patent citations made by country i to country j or made by country j to country i.
- P_{it} and P_{jt} are the number of US patent applications by countries i and j, respectively.
- $Border_{ij}$ is a dummy variable that takes a value of unity if i and j share a land border, and is zero otherwise.
- $LDist_{ij}$ is the log of the distance between i and j.
- $ComLang_{ij}$ is a dummy variable that takes a value of unity if i and j have a common language, and is zero otherwise.

- $ComCol_{ij}$ is a dummy variable that takes a value of unity if i and j were ever colonies of the same colonizer after 1945, and is zero otherwise.
- $Colony_{ij}$ is a dummy variable that takes a value of unity if i ever colonized j or vice versa, and is zero otherwise.
- $Onein_{ijt}$ is a dummy variable that takes a value of unity if either i or j was a GATT/WTO member at t, and is zero otherwise.
- $Bothin_{ijt}$ is a dummy variable that takes a value of unity if both i and j were GATT/WTO members at t, and is zero otherwise.
- $Regional_{ijt}$ is a dummy variable that takes a value of unity if i and j both belonged to the same RTA at t, and is zero otherwise.
- GSP_{ijt} is a dummy variable that takes a value of unity if i was a Generalized System of Preferences (GSP) beneficiary of j or vice versa at t, and is zero otherwise.[11]
- ε_{ijt} represents the effect of omitted influences on patent citations.

In our gravity equation, the coefficients of interest are γ_1, γ_2, γ_3, and γ_4. Of these coefficients, the most interesting is γ_3. This coefficient measures the effect of RTAs on technology spillovers under the assumption that all RTAs have the same effect on technology spillovers. Following Rose (2004, 2005), the RTAs represented by the dummy variable *Regional* include the EEC/EC/EU, US–Israel FTA, NAFTA, CARICOM, PATCRA, ANZCERTA, CACM, Mercosur, and ASEAN.[12] We also estimate the effects of individual RTAs on technology spillovers by assigning a separate dummy to each RTA.

The coefficients γ_1 and γ_2 represent the effects of the GATT/WTO on technology spillovers. The coefficient γ_1 represents the corresponding effect if one country is a member and the other is not, and γ_2 represents the corresponding effect if both countries are GATT/WTO members. The coefficient (γ_4) represents the effect of the GATT/WTO's GSP. Because we have count data on our dependent variable (patent citations), we estimate the above gravity equation by using the negative binomial model discussed by Cameron and Trivedi (1998), as is standard. In this model, the data are assumed to be generated by a Poisson process, but more flexible modeling of the variance is allowed to account for overdispersion.

[11] The GSP is a system of exemption from the rules of the WTO designed to promote economic growth in developing countries. Under the GSP system, developed countries provide preferential duty-free entry to their domestic markets for products exported from designated beneficiary countries.

[12] Besides NAFTA (already defined above), the formal names of these RTAs are: EEC/EC/EU: the European Economic Community/the European Community/the European Union; US–Israel FTA: the United States–Israel Free Trade Agreement; CARICOM: the Caribbean Community; PATCRA: the Agreement on Trade and Commercial Relations between Australia and Papua New Guinea; ANZCERTA: Australia New Zealand Closer Economic Agreement; CACM: Central American Common Market; Mercosur: Mercado Común del Sur; and ASEAN: the Association of Southeast Asian Nations.

Moreover, there are a large number of zero observations for patent citations (about 47%). The presence of a large number of zero observations raises two concerns. First, the large number of zeros causes a diversion from the normal distribution, which biases the estimated standard errors. More importantly, these zero observations might result from two quite different data generating processes. That is, countries that generate zero values for period t comprise those that never made a citation, whether they had patents or not, as well as those that, despite having made citations often in the past, did not make one at time t. To deal with these problems, we use the ZINB model. According to Cameron and Trivedi (1998), the ZINB model has the following distribution:

$$f(C_{ijt}|\boldsymbol{x}_1, \boldsymbol{x}_2, \boldsymbol{\theta}_1, \boldsymbol{\theta}_2) = \begin{cases} f_1(0|\boldsymbol{x}_1, \boldsymbol{\theta}_1) + [1 - f_1(0|\boldsymbol{x}_1, \boldsymbol{\theta}_1)] \times f_2(0|\boldsymbol{x}_2, \boldsymbol{\theta}_2) & \text{if} \quad C_{ijt} = 0, \\ [1 - f_1(0|\boldsymbol{x}_1, \boldsymbol{\theta}_1)] \times f_2(C_{ijt}|\boldsymbol{x}_2, \boldsymbol{\theta}_2) & \text{if} \quad C_{ijt} \geq 1, \end{cases}$$

where $f_1(\cdot)$ represents the distribution of the zeros generated by the first data generating process, $f_2(\cdot)$ represents the distribution of the data generating process associated with both citations already made and those not yet made, $\boldsymbol{x}_i$ $(i = 1, 2)$ denotes a vector of explanatory variables, and $\boldsymbol{\theta}_i$ $(i = 1, 2)$ denotes a vector of parameters. We suppose that $f_2(\cdot)$ follows a negative binomial distribution parameterized by $\boldsymbol{x}_2'\boldsymbol{\theta}_2$, in which $\boldsymbol{x}_2$ includes all explanatory variables in eq. (1); i.e., $\ln(P_{it} \times P_{jt})$, $Border_{ij}$, $LDist_{ij}$, $ComLang_{ij}$, $ComCol_{ij}$, $Colony_{ij}$, $Onein_{ijt}$, $Bothin_{ijt}$, $Regional_{ijt}$, and GSP_{ijt}. The distribution $f_1(\cdot)$ is logistic, and $\boldsymbol{x}_1$ includes only $\ln P_{it}$ and $\ln P_{jt}$.

We use the maximum likelihood estimation technique to estimate the parameters $\boldsymbol{\theta}_1$ and $\boldsymbol{\theta}_2$ in the ZINB model. Having estimated the ZINB model, we report the Vuong test statistics. The test statistics for the ZINB model versus the negative binomial model have standard normal distributions under the null hypothesis.

5 Data

The data on patent applications and patent citations are taken from the National Bureau of Economic Research patent database at the United States Patent and Trademark Office. 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 extract patent application and citation data from 1990 to 1999. The information used to construct the dummy variables in the gravity equation are taken from the web page of Andrew K. Rose.[13] For details of the data, see Rose (2004, 2005).

Our sample period is 1990 to 1999. The sample includes trade partner countries between which there was at least one US patent citation during that period. Our sample covers 103 countries. The countries that are included in our sample are listed in Table A.1.

Table A.2 shows the descriptive statistics of the variables and Table A.3 shows the correlations among variables.

[13] http://faculty.haas.berkeley.edu/arose/

6 Empirical Results

In this section, we report our estimation results. We first report our findings from the negative binomial model. We then report the results from the ZINB model.

The estimation results from the negative binomial model are reported in Table 1. Columns (1) to (3) report the estimation results for the whole sample, and columns (4) to (6) report the estimation results for the sample that excludes the US. Because the number of patent citations made or received by the US is unevenly larger than those of other countries, it is worth examining how the results are affected by excluding the US.

As shown in Table 1, most of the control variables have highly significant coefficients with the expected signs in all regressions. The coefficient of the log of the product of US patents held by both trade partners ($\ln(P_i \times P_j)$) is positive and significant. This means that trade partners holding more patents experience higher technology spillovers. The land border dummy (*Border*) and the common language dummy (*ComLang*) have positive and significant coefficients in all regressions. The log of the distance between the trade partners (*LDist*) has a negative and significant coefficient in many cases, but the coefficient is insignificant in columns (1) and (2). As shown later by Table 2, the insignificant coefficient in the regression for the whole sample is because of the strong effect of the US. The above results imply that countries sharing a language or land border exchange technological knowledge more, whereas geographical distance tends to reduce knowledge spillovers. These results imply that technology spillovers have similar determinants to internationally traded goods. The latter result is consistent with existing ones (Jaffe and Trajtenberg, 1999; Peri, 2005), but the former is new to the literature. The effects of colonial history on technology spillovers, represented by *ComCol* and *Colony*, are mixed. The coefficient of *ComCol* is negative and significant in the regressions for the whole sample but is insignificant when the US is excluded from the sample. By contrast, the coefficient of *Colony* is insignificant in the regressions for the whole sample but is positive and significant when the US is excluded. These results imply that the effects of colonial history on technology spillovers are different from those on internationally traded goods.

In columns (1) and (2) of Table 1, *Regional* has a significantly positive coefficient. This implies that RTAs have a positive and significant effect on technology spillovers in the sense that trade partners belonging to the same RTA have more patent citations. The results in columns (4) and (5) show that positive and significant effect of RTAs on technology spillovers remains when the US is excluded from the sample, although the coefficient is significant at a slightly higher level (i.e., 5% or 10% rather than 1%) than before. The coefficient of *Regional* captures the effect of RTAs under the assumption that all RTAs have the same effect. We also estimate the effects of individual RTAs by including a separate dummy for each of the eight RTAs. The results are shown in columns (3) and (6). Coefficients are positive and significant for the US–Israel FTA, NAFTA, CARICOM, and CACM. Although coefficients are insignificant for PATCRA and ASEAN in the whole sample, they are positive and significant when the US is excluded. We find that the effects of EEC/EC/EU and Mercosur on technology spillovers are insignificant.

We also estimate the effect of the GATT/WTO.[14] The significantly negative coefficient of *Onein* (in columns (1) and (4)) and the significantly positive coefficient of *Bothin* (in columns (2) and (5)) indicate that the GATT/WTO enhances technology spillovers if both trade partners are GATT/WTO members but hinders technology spillovers between member and nonmember countries. *GSP* also affects technology spillovers negatively, as shown by the results in columns (1), (2), (4), and (5). These effects of the GATT/WTO and GSP on technology spillovers differ from their effects on trade. Rose (2004) finds that the effects of *Onein* and *Bothin* are both insignificant in a number of econometric specifications, whereas *GSP* has a strongly positive effect on trade. Although our sample period is shorter than that of Rose (2004), we find that *Bothin* has a significantly positive effect on technology spillovers, whereas *Onein* and *GSP* have significantly negative effects.

Table 2 reports the estimation results from the ZINB model. As in Table 1, the estimation results for the whole sample are reported in columns (1) to (3), and the results based on excluding the US are reported in columns (4) to (6). Although the results from the ZINB model are generally consistent with those from the negative binomial model, there are differences between the results in Tables 1 and 2. First, the coefficient of *LDist* is positive and significant in the whole sample (see columns (1) to (3)). The reason is that the number of patent citations made or received by the US is unevenly larger than those of other countries. Consequently, excluding the US has a strong effect on the estimated coefficient of *LDist*. Excluding the US from the sample (as in columns (4) to (6)) gives the coefficient of *LDist* its expected sign. Second, although the positive and significant coefficient of *Regional* is unchanged, the coefficients of some of the dummies for individual RTAs change sign. The estimated coefficient of the EEC/EC/EU dummy is positive and significant. This result implies that Europe's RTA facilitates technology spillovers between major European countries. The coefficients of CARICOM and CACM are insignificant in the whole sample (in column (3)), whereas they are positive and significant when the US is excluded, as before (see column (6)). The coefficients of PATCRA and Mercosur are negative and significant in the whole sample (in column (3)), whereas their estimated effects reported in column (6) are consistent with those in Table 1.

The significantly positive Vuong test statistics in all regressions indicate that the ZINB model is superior to the negative binomial model.

The coefficient of *Regional* in Table 2 is positive and significant, regardless of whether the US is included. The coefficients on the variables representing RTAs of which the US is a member (i.e., the US–Israel FTA and NAFTA) are positive and significant in the whole sample. In addition, the estimated coefficients of the other RTAs (except for Mercosur) are also positive and significant when the US is excluded from the sample. These results indicate that RTAs generally have positive effects

[14] As shown in Table A.3, the correlation between *Onein* and *Bothin* is very high. Thus, we estimate the effects of *Onein* and *Bothin* in separate regressions.

on technology spillovers between trade partners.

7 Conclusions

In this paper, we investigated empirically whether regional trade agreements (RTAs) enhance technology spillovers among member countries. We used patent citation data from the US Patent and Trademark Office as a proxy for technology spillovers. By using the negative binomial model, we found that technology spillovers, as measured by patent citations between trade partners, are higher if these countries are members of the same RTA. We also found that most individual RTAs have significantly positive effects on technology spillovers. Our major findings were confirmed by the estimates obtained from the zero-inflated negative binomial model, which addresses the econometric issue that arises from a large number of countries recording a value of zero for current patent citations. We also found that the GATT/WTO has a positive effect on technology spillovers among member countries, whereas it has a negative effect on technology spillovers between members and nonmembers. The Generalized System of Preferences negatively affects technology spillovers, which contrasts with its effect on international trade in goods.

As did Peri (2005), we found that the gravity model performs well in analyzing technology spillovers. Thus, we suggest that further studies of technology spillovers based on a gravity-type approach are worthwhile.

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Table 1: Negative Binomial Estimates of US Patent Citations between Trade Partners

Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(P_i \times P_j)$	0.70***	0.70***	0.73***	0.83***	0.83***	0.85***
	(12.08)	(12.06)	(16.19)	(124.53)	(124.59)	(128.49)
Border	0.40***	0.40***	0.29***	0.20***	0.20***	0.20***
	(7.11)	(7.00)	(5.42)	(5.52)	(5.53)	(5.47)
LDist	0.00	0.00	−0.09***	−0.14***	−0.14***	−0.18***
	(0.06)	(0.07)	(−3.65)	(−13.03)	(−13.00)	(−17.75)
ComLang	0.46***	0.46***	0.45***	0.18***	0.18***	0.20***
	(4.42)	(4.44)	(4.66)	(6.47)	(6.50)	(6.98)
ComCol	−0.97***	−0.94***	−0.69***	−0.23	−0.22	−0.20
	(−2.76)	(−2.73)	(−2.77)	(−1.15)	(−1.11)	(−1.04)
Colony	0.01	0.01	0.08	0.24***	0.24***	0.23***
	(0.14)	(0.14)	(0.86)	(5.47)	(5.47)	(5.17)
Onein	−0.30**			−0.11***		
	(−2.42)			(−2.78)		
Bothin		0.29**			0.10**	
		(2.35)			(2.52)	
GSP	−0.46***	−0.47***		−0.28***	−0.28***	
	(−4.39)	(−4.38)		(−14.01)	(−14.03)	
Regional	0.18***	0.18***		0.05*	0.05**	
	(2.98)	(2.99)		(1.94)	(1.98)	
EEC/EC/EU			0.08			0.04
			(1.37)			(1.62)
$US--Israel$			1.33***			
			(9.26)			
NAFTA			1.03***			0.41***
			(6.31)			(3.54)
CARICOM			5.24*			6.56***
			(1.99)			(4.05)
PATCRA			0.18			0.81***
			(0.79)			(5.87)
CACM			2.56**			4.02***
			(2.13)			(3.72)
Mercosur			−0.59			0.23
			(−1.42)			(0.71)
ASEAN			0.43			0.85***
			(1.12)			(2.61)
No. of Obs.	19854	19854	19854	18464	18464	18464
log likelihood	−53555.2	−53557.0	−53762.8	−36348.1	−36349.3	−36451.5

Notes: (1) The sample covers the period between 1990 and 1999, and includes trade partner countries that have at least one US patent citation between them in the sample period.

(2) ***, **, and * denote 1%, 5%, and 10% significance levels, respectively.

(3) The values in parentheses are t-statistics.

(4) The regressions include year dummies.

Table 2: Zero-inflated Negative Binomial Estimates of US Patent Citations between Trade Partners

Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(P_i \times P_j)$	0.23***	0.23***	0.26***	0.81***	0.81***	0.83***
	(86.50)	(86.56)	(105.44)	(223.79)	(223.75)	(230.90)
Border	0.48***	0.54***	0.66***	0.21***	0.22***	0.22***
	(4.30)	(4.82)	(5.25)	(5.04)	(5.07)	(4.96)
LDist	0.25***	0.26***	0.39***	−0.14***	−0.14***	−0.18***
	(9.58)	(9.75)	(12.31)	(−12.88)	(−12.86)	(−16.87)
ComLang	0.86***	0.84***	0.57***	0.17***	0.17***	0.20***
	(12.42)	(12.16)	(7.30)	(6.72)	(6.74)	(7.52)
ComCol	−4.30***	−3.97***	−3.54***	−0.28**	−0.28**	−0.24*
	(−17.20)	(−15.22)	(−12.30)	(−2.09)	(−2.04)	(−1.69)
Colony	−0.27**	−0.25**	0.29**	0.23***	0.23***	0.23***
	(−2.24)	(−2.12)	(2.28)	(4.97)	(4.98)	(4.91)
Onein	−1.78***			−0.13***		
	(−28.22)			(−4.26)		
Bothin		1.77***			0.12***	
		(28.11)			(3.93)	
GSP	−1.55***	−1.55***		−0.29***	−0.29***	
	(−34.54)	(−34.45)		(−15.96)	(−15.98)	
Regional	0.17**	0.16**		0.06**	0.06**	
	(2.22)	(2.07)		(2.24)	(2.27)	
EEC/EC/EU			0.41***			0.06**
			(4.50)			(2.07)
$US--Israel$			1.77***			
			(3.40)			
NAFTA			2.18***			0.40*
			(5.94)			(1.83)
CARICOM			2.23			19.12***
			(0.90)			(15.56)
PATCRA			−2.13***			0.77***
			(−4.04)			(4.16)
CACM			−1.70			3.81***
			(−0.84)			(3.62)
Mercosur			−4.08***			0.11
			(−6.48)			(0.30)
ASEAN			0.70			0.79***
			(1.06)			(2.74)
No. of Obs.	19854	19854	19854	18464	18464	18464
log likelihood	−55527.9	−55528.8	−56371.6	−37428.5	−37429.8	−37541.4
Vuong test	8.58***	8.58***	7.95***	4.81***	4.81***	3.98***

Notes: (1) The sample covers the period between 1990 and 1999, and includes trade partner countries that have at least one US patent citation between them in the sample period.

(2) ***, **, and * denote 1%, 5%, and 10% significance levels, respectively.

(3) The values in parentheses are t-statistics.

(4) Vuong test denotes a test of the ZINB model against the negative binomial model. The test statistics are standard normally distributed under the null hypothesis.

(5) The regression equation for zero counts includes $\ln(P_i)$ and $\ln(P_j)$.

The estimates are available upon request.

(6) The regressions include year dummies.

Table A.1: Sample Countries

No.	Country	No.	Country	No.	Country	No.	Country
1	ANTIGUA AND BARBUDA	27	EL SALVADOR	53	KOREA,SOUTH(R)	79	RUSSIA
2	ARGENTINA	28	ESTONIA	54	KUWAIT	80	SAUDI ARABIA
3	ARMENIA	29	FIJI	55	LATVIA	81	SENEGAL
4	AUSTRALIA	30	FINLAND	56	LEBANON	82	SINGAPORE
5	AUSTRIA	31	FRANCE	57	LITHUANIA	83	SLOVENIA
6	AZERBAIJAN	32	GERMANY	58	LUXEMBOURG	84	SOUTH AFRICA
7	BAHRAIN	33	GHANA	59	MADAGASCAR	85	SPAIN
8	BARBADOS	34	GREECE	60	MALAYSIA	86	SRI LANKA
9	BELARUS	35	GUATEMALA	61	MALTA	87	SURINAME
10	BELGIUM	36	GUINEA	62	MAURITIUS	88	SWEDEN
11	BERMUDA	37	GUYANA	63	MEXICO	89	SWITZERLAND
12	BOLIVIA	38	HAITI	64	MOROCCO	90	SYRIA
13	BRAZIL	39	HONDURAS	65	NETHERLANDS	91	TANZANIA
14	BULGARIA	40	HUNGARY	66	NEW ZEALAND	92	THAILAND
15	CANADA	41	ICELAND	67	NICARAGUA	93	TUNISIA
16	CHILE	42	INDIA	68	NIGER	94	TURKEY
17	CHINA	43	INDONESIA	69	NIGERIA	95	UGANDA
18	COLOMBIA	44	IRAN	70	NORWAY	96	UKRAINE
19	COSTA RICA	45	IRELAND	71	OMAN	97	UNITED KINGDOM
20	CROATIA	46	ISRAEL	72	PAKISTAN	98	UNITED STATES
21	CYPRUS	47	ITALY	73	PANAMA	99	URUGUAY
22	CZECH REPUBLIC	48	JAMAICA	74	PARAGUAY	100	UZBEKISTAN
23	DENMARK	49	JAPAN	75	PERU	101	VENEZUELA
24	DOMINICA	50	JORDAN	76	PHILIPPINES	102	VIETNAM
25	ECUADOR	51	KAZAKHSTAN	77	POLAND	103	ZIMBABWE
26	EGYPT	52	KENYA	78	PORTUGAL		

Table A.2: Descriptive Statistics

Variable	No. of Obs	Mean	Std.Dev.	Min	Max
C	19854	232.46	2908.22	0.00	134135.00
$\ln(P_i \times P_j)$	19854	8.44	6.16	-6.91	21.88
$Border$	19854	0.03	0.18	0.00	1.00
$LDist$	19854	8.15	0.90	4.80	9.42
$ComLang$	19854	0.16	0.37	0.00	1.00
$ComCol$	19854	0.01	0.09	0.00	1.00
$Colony$	19854	0.03	0.18	0.00	1.00
$Regional$	19854	0.07	0.25	0.00	1.00
GSP	19854	0.52	0.50	0.00	1.00
$Onein$	19854	0.15	0.36	0.00	1.00
$Bothin$	19854	0.85	0.36	0.00	1.00

Table A.3: Correlations of the Variables

	$\ln(P_i \times P_j)$	*Border*	*LDist*	*ComLang*	*ComCol*	*Colony*	*Regional*	*GSP*	*Onein*	*Bothin*
$\ln(P_i \times P_j)$	1.000									
Border	0.084	1.000								
LDist	−0.102	−0.421	1.000							
ComLang	−0.030	0.110	0.045	1.000						
ComCol	−0.044	−0.005	−0.023	0.145	1.000					
Colony	−0.012	0.043	−0.027	0.313	−0.017	1.000				
Regional	0.174	0.214	−0.437	−0.021	0.006	0.010	1.000			
GSP	−0.227	−0.172	0.331	−0.049	−0.096	0.012	−0.205	1.000		
Onein	−0.154	−0.055	−0.005	−0.128	−0.023	−0.054	−0.114	−0.004	1.000	
Bothin	0.157	0.049	0.005	0.130	0.018	0.055	0.115	0.009	−0.992	1.000