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Naoto JINJI Yukiko SAWADA

Xingyuan ZHANG Shoji HARUNA

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

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Gravity for Cross-border Licensing and the Impact of Deep Trade Agreements: Theory and Evidence*

Naoto JINJI†‡ Yukiko SAWADA§ Xingyuan ZHANG¶ Shoji HARUNA‖

Abstract

We examine whether deep regional trade agreements (RTAs) facilitate cross-border technology transfer. The mode of technology transfer we focus on is licensing. We first derive a micro-founded structural gravity model for cross-border licensing from a model in which heterogeneous firms choose to supply their goods to foreign markets through export, foreign direct investment, or licensing. We show several comparative statics results regarding the effects of changes in the fixed costs of serving the destination country, the freeness of trade, and the strength of intellectual property rights (IPR) protection on bilateral flows of licensing revenues. We then empirically test our theoretical predictions using data on cross-border flows of royalties and license fees for 49 countries in the period 1995–2012. Various dummy variables and indexes are used to capture the impact of shallow and deep RTAs on cross-border licensing. Consistent with our theoretical predictions, we find that improved access to the destination market through a deep RTA and stronger IPR protection through an RTA with legally enforceable IPR provisions and technology-related provisions increase bilateral flows of licensing revenues. By contrast, a shallow RTA without IPR provisions does not increase cross-border licensing revenues.

Keywords: regional trade agreement; deep integration; technology transfer; licensing; gravity model.
JEL classification: F15; O33.

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

‡Research Institute of Economy, Trade and Industry (RIETI).

§Faculty of Economics, Ryukoku University, 67 Fukakusa Tsukamoto-cho, Fushimi-ku, Kyoto 612-8577, Japan

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

‖Faculty of Economics, Fukuyama University, 985-1 Sanzo, Higashimura-machi, Fukuyama 729-0292, Japan.

1 Introduction

Many firms engage in cross-border technology transfers through licensing. Total bilateral flows of royalties and license fees in the world have steadily increased over at least the last two decades (see Figure 1).[1] There are many examples of cross-border licensing. For example, starting in 1970, Burberry, a British luxury fashion house, supplied Burberry-branded products to the Japanese market through a licensing agreement with Sanyo Shokai, a Japanese apparel company, which had teamed up with Mitsui & Co., a Japanese trading house (Moore and Birtwistle, 2004). However, although Burberry's business in the Japanese market based on this relationship was quite successful, Burberry terminated its licensing agreement with Sanyo in June 2015 because of Burberry's global brand strategy. More recently, Advanced Micro Devices Inc. (AMD), a Silicon Valley chip company, struck a joint venture with Chinese private and state-owned entities in 2016 (The Wall Street Journal, September 26, 2018). AMD licensed microprocessor technology to the venture, which was used to develop new computer chips. AMD received about $140 million in license fees in 2017.

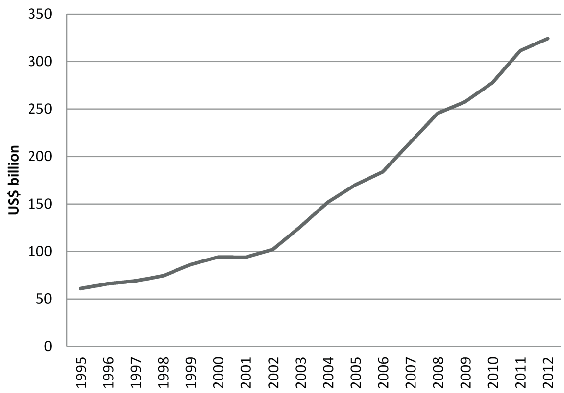

Figure 1: World Total Bilateral Flows of Royalties & License Fees (1995–2012, US$ billion)
Source: Authors' calculation from OECD data.

In general, when a firm licenses its technology, it faces the risk of imitation. For example, in 2006, DuPont licensed its Chinese partner, Zhangjiagang Glory, to produce and distribute textile polymers called Sorona (The Wall Street Journal, September 26, 2018). However, in 2013, DuPont did not renew the license due to suspicions that the Chinese firm was stealing its intellectual property to sell products similar to Sorona, and in 2017 filed two arbitration cases in China, alleging patent infringement.

Another major global trend, apart from the increase in cross-border licensing, has been growing regional economic integration over the past quarter century or so. A key development in this context

[1] Exports and imports of royalties and license fees are recorded as part of international trade in services.

is the tendency to pursue so-called "deep integration" in regional trade agreements (RTAs) (Baldwin, 2011). To this end, many RTAs now include provisions on the harmonization of intellectual property rights (IPR) regimes. Moreover, some RTAs explicitly include provisions that aim to stimulate technology transfer. For example, the Peru–United States Trade Promotion Agreement includes an article (Article 16.12) to promote innovation and technological development through collaborative scientific research projects and transfer of technology.

Based on these two parallel trends, the question we seek to answer in this study is whether regional economic integration facilitates cross-border technology transfer through licensing. In particular, given the fact that many recent RTAs pursue "deeper" integration, we ask whether there are any differences between shallow and deep RTAs in the impact on cross-border licensing. If the answer is "Yes," this has important implications for the establishment of RTAs.

To address these questions, we start by estimating a conventional gravity equation, applied to cross-border licensing. The results suggest that the gravity equation explains bilateral licensing revenue flows remarkably well. To our knowledge, however, no previous study has employed a gravity approach to investigate what factors facilitate or impede cross-border licensing.[2] Therefore, in order to examine the impact of RTAs on cross-border technology transfer through licensing, we need to construct a theoretically founded gravity model for cross-border licensing.

Against this background, we develop a monopolistically competitive trade model in which heterogeneous firms choose to supply their goods to foreign markets through export, foreign direct investment (FDI), or licensing. From this model, we derive a structural gravity equation for cross-border licensing revenues. Next, we perform comparative statics analysis to examine the effects of changes in the fixed costs of serving the destination country, the freeness of trade, and the strength of IPR protection on bilateral flows of licensing revenues. We show that stronger IPR protection increases bilateral licensing revenue flows. Further, under certain conditions, an increase in the freeness of trade in terms of a reduction in variable trade costs decreases cross-border licensing revenues, while a fall in the fixed costs of serving the destination country increases cross-border licensing revenues. Moreover, if the initial level of the freeness of trade is relatively low, the combination of an increase in the freeness of trade and a strengthening of IPR protection increases cross-border licensing revenues.

To empirically test the theoretical predictions derived from the comparative statics analysis, we next estimate the gravity model for licensing and examine how the establishment of RTAs affects cross-border licensing, distinguishing between deep and shallow RTAs. We measure cross-border licensing using data on bilateral flows of royalties and license fees. The nature of RTAs is measured by employing various dummy variables and indexes. In addition to the usual RTA dummy, we construct dummy variables to capture the effects of RTAs with legally enforceable Trade-Related Aspects of

[2]See Anderson (2011) for an overview of the application of gravity models to various bilateral transactions other than trade in goods.

Intellectual Property Rights (TRIPS) provisions, RTAs with legally enforceable IPR provisions, and RTAs without legally enforceable IPR provisions. In our estimation, we use the last two dummies to distinguish deeper RTAs with legally enforceable IPR provisions from shallow ones. Moreover, we construct two additional indexes following Limão (2016) that measure the depth and breadth of RTAs. One index measures the depth of RTAs based on the coverage of depth-related provisions. The other index measures the breadth of RTAs in terms of the coverage of provisions in technology-related policy areas.

To estimate the gravity model, we employ the Poisson pseudo-maximum likelihood (PPML) estimator with time-varying source country (i.e., licenser) fixed effects, time-varying destination country (i.e., licensee) fixed effects, and source-destination-pair fixed effects, which is recommended in the gravity literature (Anderson and van Wincoop, 2003; Falley, 2015; Head and Mayer, 2014; Santos Silva and Tenreyro, 2006, 2011; Yotov et al., 2016). In order to obtain reliable estimates of the effects of shallow and deep RTAs, it is important to address the potential endogeneity of RTAs. Possible sources of such endogeneity are omitted variable bias and reverse causality (Baier and Bergstrand, 2007). Baier and Bergstrand (2007) and Yotov et al. (2016) therefore 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: 21) into account. We follow the recommendation in the gravity literature (Baier and Bergstrand, 2007; Yotov et al., 2016) and include source-destination-pair fixed effects in our estimations to address this endogeneity issue.

Our main empirical findings are as follows. We find that both deep RTAs in general and deep RTAs with legally enforceable IPR provisions or technology-related provisions increase cross-border flows of licensing revenues. We also find that shallow RTAs without IPR provisions tend to fail to enhance flows of licensing revenues. These findings support the predictions of our theoretical model.

This study is related to a number of previous studies. First, there are a number of theoretical studies that analyze the impact of stronger IPR protection in developing countries on innovation, licensing, input procurement, technology transfer, and trade by firms in developed countries (Naghavi, 2007; Naghavi et al., 2017; Tanaka et al., 2007; Yang and Maskus, 2001b; Yang and Maskus, 2009). Employing a simple duopoly framework with one Northern and one Southern firm, Naghavi (2007), for example, examines how the government in the South chooses its IPR policy strategically to manipulate the Northern firm's decision regarding the level of R&D investment and the mode it uses to supply the Southern market (export or FDI). He shows that a stringent IPR regime is always optimal for the South as it induces technology transfer through FDI by the Northern firm in less R&D-intensive industries and stimulates innovation by the Northern firm to engage in a predatory level of R&D in more R&D-intensive industries.

Second, our study is related to empirical research on the relationship between IPR protection on the one hand and licensing and royalty payments on the other. Studies in this strand of the literature include Yang and Maskus (2001a), Branstetter et al. (2006), and Ivus et al. (2017). Specifically, using data on US firms' receipts of royalties and license fees and employing reduced-form regressions, Yang and Maskus (2001a) examine the effects of IPR protection on the flow of licensing. They find that when the initial degree of patent protection is higher than a certain critical level, US firms' royalty and licensing receipts from unaffiliated foreign firms are greater the stronger patent rights in the technology recipient country are. In contrast, IPRs have less significant effects on US firms' receipts from affiliated foreign firms. Branstetter et al. (2006) examine whether IPR reforms increase international technology transfers within US multinational firms and find that IPR reforms in host countries do increase royalty payments from foreign affiliates. Meanwhile, using micro data on affiliated and unaffiliated technology licensing by US multinational firms, Ivus et al. (2017) examine how patent protection in developing countries affects the technology licensing strategy of US multinational firms to affiliated and unaffiliated foreign firms. They find that a strengthening of patent protection in the host country increases the incentive to license technology to unaffiliated firms. On the other hand, in the case of licensing to affiliated firms, the volume of licensing falls among complex-technology firms but rises among simple-technology firms. For firms producing simple-technology products, the positive appropriability effect on affiliated licensing is strong enough for the composition of their licensing to fully shift towards affiliated parties. However, none of these studies investigate how the establishment of RTAs — particularly, deep RTAs — affects cross-border technology transfer through licensing.

The third strand our study is related to is the growing literature on the impact of deep RTAs.[3] Dür et al. (2014) develop an original dataset on deep integration and show that RTAs increase trade flows and that this positive effect is largely driven by deep integration. Meanwhile, Orefice and Rocha (2014) analyze the impact of deep RTAs on production networks, while Osnago et al. (2016) examine whether deep RTAs increase vertical FDI. Further, Mattoo et al. (2017) analyze how deep integration affects the trade creation and trade diversion effects of RTAs. Finally, Jinji et al. (2019) examine whether deep RTAs enhance international technology spillovers using patent citation data and find that the depth of integration does influence technology spillovers and that deep integration in a broad sense has a greater impact on technology spillovers than technology-related provisions.

The remainder of this study is organized as follows. Sections 2 provides the motivating evidence for our study. Specifically, estimating a traditional gravity equation suggests that, as in the case of trade in goods and factor movements, such a model explains cross-border transactions in licensing quite well. Next, Section 3 presents our theoretical framework and derives a micro-founded structural gravity model for cross-border licensing. Section 4 then explains the empirical framework and describes the data employed in our empirical analysis, while Section 5 presents our empirical results. Finally, Section 6 provides concluding remarks.

[3] See Maggi and Ossa (2021) for a survey of the literature. With regard to theoretical investigations on the differential effects of deep versus shallow trade agreements, see, for example, Grossman et al. (2021) and Maggi and Ossa (2020).

2 Motivating Evidence: Gravity for Cross-border Licensing

We begin our discussion by presenting our motivating evidence. In the trade literature, it is well-known that gravity models explain not only international flows of goods but also international flows of production factors such as labor and capital quite well (Anderson, 2011; Head and Mayer, 2014).[4] To the best of our knowledge, no previous study has examined whether gravity models can also explain international flows in licensing revenues.

Therefore, as a first step, we estimate a traditional gravity equation for bilateral flows in licensing revenues. As the dependent variable, we use the cross-border royalty and licensing revenues of 49 countries spanning the period 1995–2012,[5] which are given by $\ln(RLF_{ijt})$ in the ordinary least squares (OLS) estimation and by RLF_{ijt} in the PPML estimation, where firms in country i are licensers and firms in country j are licensees.[6] Standard gravity variables are used as explanatory variables: $\ln(Dist_{ij})$ is the logarithm of the bilateral distance between countries i and j; $Lang_{ij}$ is a dummy variable that is one if i and j share a common official language and zero otherwise; $Contig_{ij}$ is a dummy variable that is one if i and j share a common border and zero otherwise; $Colony_{ij}$ is a dummy variable that is one if i and j had any colonial ties in the past and zero otherwise; and $Smctry_{ij}$ is a dummy variable that is one if one country was part of the other in the past and zero otherwise.[7] In addition, we include WTO_{ijt} and RTA_{ijt} dummies. WTO_{ijt} is a dummy variable that takes the value one if both i and j were GATT/WTO members in year t and zero otherwise.[8] RTA_{ijt} is a dummy variable that takes the value one if countries i and j both belonged to a common RTA in year t and zero otherwise.[9] Finally, $\ln(Y_{it})$ and $\ln(Y_{jt})$ are the GDP of country i (source country) and country j (destination country) in year t, respectively.[10]

[4] Applications of gravity models to FDI include Anderson et al. (2019), Head and Ries (2008), and Kleinert and Toubal (2010). Specifically, Anderson et al. (2019) develop a multi-country dynamic trade model with domestic investment in physical capital and FDI in the form of global technology capital, which has a non-rival or "joint" property, used to produce a single tradable consumption good. FDI from country i to country j provides the technology capital stock available in i for production in j subject to possible bilateral FDI frictions between the two countries. They then derive a structural gravity system for the value of FDI stock as part of the "upper level" structural gravity equations (where the "upper level" is the solution of the dynamic optimization problem). However, although their characterization of FDI focuses on the technology transfer aspect, the way they treat FDI in their model is quite different from licensing. Another related study is that by Eaton and Kortum (2018), who construct a model for the trade in goods and services in which technology is provided as an intangible asset. In their model, the value of intangible services flows in the form of royalties to the source country of the intangible assets. Yet, while their model partly captures the nature of royalty payments, they do not derive a gravity equation for royalty payments.

[5] For details of the data, see Section 4.2.

[6] In other words, firms in country j pay royalties and license fees to firms in country i.

[7] All of the gravity variables are taken from the CEPII GeoDist database (Mayer and Zignago, 2011).

[8] The information on each country's GATT/WTO membership is taken from the WTO website.

[9] The data for the RTA dummy are taken from the database provided by Mario Larch (Egger and Larch, 2008).

[10] The data for countries' GDP are taken from the World Bank's World Development Indicators.

Table 1: Gravity for Cross-border Licensing

	(1) OLS	(2) PPML
$\ln(Dist_{ij})$	-0.839^{***}	-0.396^{***}
	(0.049)	(0.070)
$Lang_{ij}$	0.223^{**}	0.150
	(0.111)	(0.160)
$Contig_{ij}$	0.011	-0.348^{*}
	(0.150)	(0.177)
$Colony_{ij}$	0.608^{***}	0.106
	(0.142)	(0.156)
$Smctry_{ij}$	0.731^{***}	0.018
	(0.246)	(0.289)
WTO_{ijt}	0.202^{***}	0.242^{**}
	(0.067)	(0.118)
RTA_{ijt}	0.141^{**}	0.291^{**}
	(0.056)	(0.140)
$\ln(Y_{it})$	0.947^{***}	-0.036
	(0.148)	(0.474)
$\ln(Y_{jt})$	1.611^{***}	1.672^{***}
	(0.128)	(0.230)
Year FE	Yes	Yes
Source country FE	Yes	Yes
Destination country FE	Yes	Yes
Adjusted R^2	0.8163	0.8489
Log likelihood		-608542.7
No. of obs.	33,987	35,735

Notes: (a) The dependent variable is $\ln(RLF_{ijt})$ in column (1) and RLF_{ijt} in column (2). (b) ***, **, and * denote 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.

The results are presented in Table 1, where column (1) shows those obtained using OLS, while column (2) shows those obtained using the PPML estimation. Both estimations include year fixed effects, source-country fixed effects, and destination-country fixed effects. Columns (1) and (2) both suggest that the gravity equation performs well in explaining cross-border flows of licensing revenues. Although the estimated coefficients on $\ln(Dist_{ij})$ are slightly smaller than those in similar estimations for trade in goods (see, e.g., Head and Mayer, 2014, Yotov et al., 2016), they are negative and statistically and economically significant. Moreover, the estimated coefficients for most of the other explanatory variables have the expected signs.

The question that arises from the results in Table 1 is why gravity works for international licensing. In the case of international trade in goods, bilateral distance is interpreted as a proxy of variable trade costs. By contrast, cross-border licensing does not incur variable trade costs. We therefore need to discover why cross-border licensing falls as the geographical distance between two countries increases.

The answer we propose is the following: when a firm in one country supplies its goods to the market in another country, it incurs supply costs, which depend on what we call the overall bilateral accessibility (OBA) of the destination market from the supplier's country. OBA represents the ease of access to the destination market for firms from the source country. This ease of access and the associated costs do not depend on the mode of supply (e.g., export, FDI, or licensing), although a particular mode of supply may incur some additional costs. We regard these costs to take the form of fixed rather than variable costs that increase in the geographic distance from the supplier to the destination market.

3 Theoretical Framework

In this section we derive a micro-founded structural gravity model for licensing. Our theoretical framework extends the framework developed by Helpman et al. (2004) and Helpman et al. (2008) so as to incorporate licensing and imitation into the model.

3.1 Demand

Consider a world with J countries, indexed by $j = 1, 2, \ldots, J$. Every country produces and consumes a continuum of differentiated products, which are supplied in monopolistically competitive markets. A representative household's utility function in country j is given by

$$u_j = \left[\int_{l \in \Omega_j} x_j(l)^{\alpha} dl \right]^{1/\alpha}, \tag{1}$$

where $x_j(l)$ is the consumption of product l, and Ω_j is the set of products available for consumption in country j. The parameter $\alpha \in (0, 1)$ determines the elasticity of substitution across products.

Let Y_j be the income of country j, which equals total expenditure.[11] The total demand for product l in country j is then given by

$$x_j(l) = \frac{p_j(l)^{-\sigma} Y_j}{P_j^{1-\sigma}}, \tag{2}$$

where $\sigma \equiv 1/(1-\alpha)$, $p_j(l)$ is the price of product l in country j, and P_j is the ideal price index in country j:

$$P_j = \left[\int_{l \in \Omega_j} p_j(l)^{1-\sigma} dl \right]^{1/(1-\sigma)}. \tag{3}$$

3.2 Technology and the supply mode

Consider next the products in country i produced using a composite factor of production with unit cost c/φ, where c denotes the unit cost of the composite factor and φ the firm-specific productivity.[12] There are a large number of potential entrants that can enter the industry by paying a sunk entry cost of cf_E. These potential entrants face uncertainty about their productivity and the demand for their distinct products. After paying the sunk entry cost, a firm draws its productivity φ from a fixed distribution $g(\varphi)$ with cumulative distribution $G(\varphi)$ of support $[\underline{\varphi}_i, \infty)$, where $\underline{\varphi}_i > 0$. With probability $(1-\lambda) \in (0,1)$, the product produced by a firm is useless, which means that demand for the product is zero everywhere. Such a firm with no demand for its own product will become a licensee or an imitator.

After observing the outcome of the draw, the producer of a viable product decides to stay in the market or exit. If it decides to stay in the market, it incurs fixed overhead costs of cf^D. Production costs and the fixed overhead costs are the only costs for a firm to supply its product to its domestic market.

On the other hand, when a country i firm with a viable product supplies its product to the country j market ($j \neq i$), it can choose the mode of supply from three possible options: export, FDI, or licensing. Based on the discussion in the previous section, we assume that the country i firm has to incur fixed costs cf_{ij}^X to serve the country j market, which depend on the OBA of the country j market from country i. Depending on the supply mode, the fixed costs vary as follows: $f_{ij}^L = \underline{\chi} f_{ij}^X, \underline{\chi} \in (0,1)$ and $f_{ij}^I = \bar{\chi} f_{ij}^X, \bar{\chi} \in (1, \infty)$, where f_{ij}^L and f_{ij}^I respectively are the fixed costs for licensing and FDI expressed in units of the production factor. We normalize f_{ij}^X so that it corresponds to fixed costs for exporting in units of the production factor. Moreover, for simplicity, we set $\underline{\chi}$ and $\bar{\chi}$ constant. The

[11] We assume that the income of country j is the sum of income from providing labor and other factors, which we treat as a composite factor of production; the dividends that households earn from their portfolio, which we model following Chaney (2008); and tariff revenues that are redistributed to households. We explain these elements of income in Sections 3.2 and 3.4.

[12] In general, the unit cost of the composite factor is country-specific. However, since we assume away cross-country differences in production costs as a motive for FDI and licensing, we assume an identical unit cost for all countries.

range of $\underline{\chi}$ and $\bar{\chi}$ implies that $f_{ij}^L < f_{ij}^X < f_{ij}^I$ holds.[13] Moreover, exports involve variable trade costs of the iceberg type. That is, $\tau_{ij} > 1$ units of a product have to be shipped from country i to country j for one unit to arrive. FDI and licensing do not require transport costs for delivery. Note that τ_{ij} includes trade barriers such as tariffs and transport costs.[14]

In order for a country i firm to supply its product to the country j market through licensing, it has to find a licensee in country j. Potential licensees are firms that stay in the market but cannot produce their own products because there is no demand for them. Fixed licensing costs cf_{ij}^L represent all the costs necessary to engage in licensing. We assume that cf_{ij}^L is borne entirely by the licenser. The licenser receives a fraction $\delta \in (0, 1)$ of sales of the licensed product as the license fee. We assume that when a firm with productivity φ licenses its product to a firm with productivity φ', the licensed product is produced with productivity $\min\{\varphi,\ \varphi'\}$. This implies that the licenser cannot find a licensee that is more productive than itself, and the productivity of the licensee does not rise even when the licenser's productivity is higher.

3.3 Risk of imitation

When products of country i are supplied to the country j market, there is a risk of imitation. The size of the risk depends on the degree of IPR protection in country j and on the mode of supply of the product. Potential imitators are firms that stay in the market but cannot produce their own products and failed to find a licenser. If a country i product is imitated in country j, the original producer earns zero revenue in the country j market.

With regard to the relationship between the mode of supply of a product and the risk of imitation, Smith (2001) argues that a strengthening of patent rights protection in destination countries increases licensing and sales of foreign affiliates (i.e., FDI) relative to export, with the impact on licensing being stronger. This is because the impact depends on both the location of production and internalization. Under cross-border licensing, production takes place in the foreign country and outside the technology owner. Smith (2001) then uses US data on exports, foreign affiliate sales, and licensing to foreign unaffiliated firms to obtain findings that support this argument. Since stronger patent rights protection

[13] The ordering that $f_{ij}^X < f_{ij}^I$ is widely assumed in the literature, and a number of empirical studies have shown that it generally holds in the real world. By contrast, there is no agreement whether f_{ij}^L is larger or smaller than f_{ij}^X or f_{ij}^I. However, Yasar and Morrison Paul (2007) show that in the apparel and textile industries in Turkey, the average productivity of firms engaged in licensing is lower than that of firms engaged in exporting and/or FDI. Their evidence supports our assumption. The ordering of $f_{ij}^L < f_{ij}^I$ is also consistent with evidence obtained by Markusen and Xie (2017) using Chilean plant-level data, which indicates that the average productivity of foreign subsidiaries is significantly higher than that of firms engaged in licensing from foreign firms. They argue that the different productivity levels of foreign subsidiaries and licensees reflect corresponding differences in productivity levels of foreign parent firms and licensers.

[14] Tariff revenues are redistributed to households. For more detail, see footnote 11.

reduces the risk of imitation, her findings imply that the risk of imitation is highest for licensing and lowest for exports. Moreover, as mentioned in Section 1, Ivus et al. (2017) use microdata on affiliated and unaffiliated technology licensing by US multinationals and find that stronger patent protection in destination countries increases licensing to foreign unaffiliated firms relative to licensing to foreign affiliates. Using Japanese firm data on licensing contracts, Nagaoka (2009) provides evidence similar to that shown by Ivus et al. (2017).[15]

Based on the findings of previous studies (Smith, 2001; Nagaoka, 2009; Ivus et al., 2017) and the anecdote cited in the introduction, it seems reasonable to assume that the risk of imitation is highest for licensing, lowest for exports, and intermediate for FDI. Thus, let the probability of successful imitation be $\beta_{ij} \in [0, 1]$ if a firm in country i engages in licensing in country j, but otherwise the risk is zero. We assume that β_{ij} depends on the IPR regime in country j: if intellectual property (IP) is perfectly protected in country j, then $\beta_{ij} = 0, \forall i$; however, if country j provides no IP protection at all, then $\beta_{ij} = 1, \forall i$.

Note that in Section 3.8, we consider the case in which the degree of IPR protection that licensers from country i enjoy in country j can be changed by countries i and j signing a deep RTA with IPR provisions. To incorporate this possibility, the risk of imitation is assumed to be country-pair specific, i.e., β_{ij} depends on countries i and j.

3.4 Firm behavior

Since the market structure is monopolistic competition and demand takes the form of a constant elasticity of substitution (CES) function, the equilibrium price for each country i product in its domestic market is a constant markup over marginal cost:

$$p_{ii}(\varphi) = c/\varphi\alpha. \tag{4}$$

When a country i producer exports its product to the country j market, it sets a delivered price equal to

$$p_{ij}(\varphi) = \tau_{ij}c/\varphi\alpha. \tag{5}$$

Thus, the operating profits of a country i firm with productivity φ from serving the domestic market are given by

$$\pi_{ii}^D(\varphi) = (1-\alpha)\left(\frac{c}{\alpha\varphi P_i}\right)^{1-\sigma} Y_i - cf^D. \tag{6}$$

[15] However, export is not free from the risk of imitation. Ivus (2011) argues that high-tech exports to the South suffer from the risk of imitation and shows that stronger IPR protection in the South encourages high-tech exports from the North. This theoretical result is supported by Ivus's (2010) finding that the strengthening of patent rights in response to the TRIPS agreement increased developed countries' exports in patent-sensitive goods.

On the other hand, the expected additional operating profits from serving the country j market through FDI, $\pi_{ij}^I(\varphi)$, through export, $\pi_{ij}^X(\varphi)$, or through licensing to a country j licensee with productivity φ', $\pi_{ij}^L(\varphi, \varphi')$, are respectively given by

$$\pi_{ij}^I(\varphi) = (1-\alpha)\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma} Y_j - cf_{ij}^I \tag{7}$$

$$\pi_{ij}^X(\varphi) = (1-\alpha)\left(\frac{\tau_{ij} c}{\alpha\varphi P_j}\right)^{1-\sigma} Y_j - cf_{ij}^X \tag{8}$$

$$\begin{aligned}\pi_{ij}^L(\varphi, \varphi') &= (1-\alpha)(1-\beta_{ij})\delta r_{ij}^L(\varphi, \varphi') - cf_{ij}^L \\ &= (1-\alpha)(1-\beta_{ij})\delta\left(\frac{c}{\alpha \min\{\varphi,\ \varphi'\} P_j}\right)^{1-\sigma} Y_j - cf_{ij}^L,\end{aligned} \tag{9}$$

where $r_{ij}^L(\varphi, \varphi')$ in (9) denotes the revenue from selling the product in the country j market through licensing. Note that the licenser receives fraction δ of the sales in the country j market as license fees from the licensee.

3.5 Licensing in equilibrium

In this section, we derive the conditions that license fees need to satisfy in order for licensing to be actually chosen in equilibrium.[16] First, given the assumption that when a firm with productivity φ licenses its product to a firm with productivity φ', the licensed product is produced with productivity $\min\{\varphi,\ \varphi'\}$, a simple matching mechanism results in a match between a licenser with productivity φ and a licensee with the same productivity level, i.e., $\varphi' = \varphi$. Thus, $\min\{\varphi,\ \varphi'\} = \varphi$ holds in equilibrium. Second, we need to consider the possibility that the licenser or the licensee (or both) might defect. To do so, we follow Antràs and Yeaple (2014) and assume the presence of transaction costs.[17] That is, if a licenser could costlessly contract with a foreign licensee over the production of a certain amount of output, it would be able to collect the entire net surplus. In practice, however, various types of contractual imperfections and hence the presence of transaction costs will cause rent dissipation, meaning that the licenser needs to share rents with the foreign licensee.

As shown in the previous subsection, we assume that the licensee pays fraction δ of the sales in the country j market to the licenser as license fees. If this license fee payment is too large, this may

[16] In this subsection and the subsequent analysis, we treat δ as a parameter that satisfies the conditions specified in this subsection. However, it is also possible to consider the case in which the value of δ is endogenously determined through Nash bargaining between a potential licenser and a potential licensee. We show one possible solution for this case in Section A.1 in the Supplementary Appendix. Although taking an endogenously determined δ into account makes the analysis much more complicated, it does not qualitatively change the theoretical predictions of our model. For this reason, we prefer to treat δ as a parameter.

[17] There are alternative ways to examine licensing as a choice of supply mode. For example, Ethier and Markusen (1996) and Horstmann and Markusen (1987) consider the time needed for training workers to transfer technology and the firm's reputation for quality as the firm-specific asset when a firm chooses its supply mode from licensing, exporting, and FDI. We do not take these elements into account to simplify the analysis.

provide the licensee with an incentive to use the knowledge obtained through licensing and set up production of a competing variety of the product to divert a share υ of revenues from the licensed product, which requires fixed costs of f^D. This defection by the licensee is possible because of the partially nonexcludable nature of technology. To prevent such behavior by the licensee, the license fee payment needs to be sufficiently low to satisfy

$$(1-\alpha)(1-\delta)\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma} Y_j \geq \left(\frac{\upsilon}{1-\alpha}-\frac{\alpha}{1-\alpha}\right)(1-\alpha)\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma} Y_j - cf^D, \tag{10}$$

where the left-hand side is the payoff of the licensee under no defection after the license fees are paid, whereas the right-hand side is the licensee's payoff under defection. We assume that $\upsilon \geq \alpha$ holds.

On the other hand, because of the nonrival nature of technology, the licenser, who owns the technology, may not be able to commit to not using its technology to serve the foreign market via an alternative method later. Specifically, the licenser may not fully transfer its technology to the licensee and may drive the licensee's revenue to zero by exporting its "superior" version of the product. To prevent such behavior by the licenser, the license fee payment needs to be sufficiently high to satisfy

$$(1-\alpha)(1-\beta_{ij})\delta\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma} Y_j - cf_{ij}^L \geq (1-\alpha)\left(\frac{\tau_{ij}c}{\alpha\varphi P_j}\right)^{1-\sigma} Y_j - cf_{ij}^X, \tag{11}$$

where the left-hand side is the expected profits under the licensing contract and the right-hand side is the profits of the licenser under defection by exporting its good to the country j market.

Thus, both (10) and (11) are satisfied when δ is in the following range:

$$\frac{1}{1-\beta_{ij}}\left[\tau_{ij}^{1-\sigma} - (f_{ij}^X - f_{ij}^L)\frac{(\alpha\varphi P_j)^{1-\sigma}c^\sigma}{(1-\alpha)Y_j}\right] \leq \delta \leq \frac{1-\upsilon}{1-\alpha} + f^D\frac{(\alpha\varphi P_j)^{1-\sigma}c^\sigma}{(1-\alpha)Y_j}. \tag{12}$$

In the analysis below, we assume that δ satisfies (12) for all licenser-licensee pairs that sign a licensing contract, so that in equilibrium both the licenser and the licensee have no incentive to defect.

3.6 Sorting of firms

The cutoff productivity level at which a firm stays in the country i market, φ_i^D, is implicitly defined by

$$\pi_{ii}^D(\varphi_i^D) = 0. \tag{13}$$

Thus, firms with $\varphi < \varphi_i^D$ exit. Among country i firms serving the country j market, firms serving it through licensing are the least productive. The cutoff productivity for a country i firm to serve the country j market through licensing, φ_{ij}^L, is implicitly defined by

$$\pi_{ij}^L(\varphi_{ij}^L) = 0. \tag{14}$$

Thus, firms with $\varphi_i^D < \varphi < \varphi_{ij}^L$ serve only the domestic market.

The cutoff productivity for a country i firm to be indifferent between licensing and exports, φ_{ij}^X, is defined by

$$\pi_{ij}^X(\varphi_{ij}^X) = \pi_{ij}^L(\varphi_{ij}^X). \tag{15}$$

Thus, firms with $\varphi_{ij}^L < \varphi < \varphi_{ij}^X$ serve the country j market through licensing. Finally, the cutoff productivity for a country i firm to be indifferent between export and FDI, φ_{ij}^I, is defined by

$$\pi_{ij}^I(\varphi_{ij}^I) = \pi_{ij}^X(\varphi_{ij}^I). \tag{16}$$

Thus, firms with $\varphi_{ij}^X < \varphi < \varphi_{ij}^I$ serve the country j market through export and firms with $\varphi_{ij}^I < \varphi < \infty$ serve it through FDI.

Recall that the support of the productivity distribution in country i is $[\underline{\varphi}_i, \infty)$. Thus, depending on the relative level of the cutoff productivities φ_{ij}^L, φ_{ij}^X, φ_{ij}^I, and $\underline{\varphi}_i$, some of the supply modes from i to j may be zero.

3.7 Bilateral flows of licensing revenues

Next, we derive equations for bilateral flows of licensing revenues. Following Chaney (2008), we assume that the mass of firms in country i, M_i, is proportional to the size of the market in country i, Y_i. We also assume that productivity in country i follows a Pareto distribution such that

$$G(\varphi) = 1 - \left(\frac{\underline{\varphi}_i}{\varphi}\right)^k, \tag{17}$$

where k is the shape parameter of the Pareto distribution and it is assume that $k > \sigma - 1$.

Since f_{ij}^X represents the fixed costs associated with the bilateral accessibility of the country j market, changes in f_{ij}^X capture changes in fixed costs that are common to all supply modes in serving the country j market. Moreover, we define $T_{ij} \equiv \tau_{ij}^{1-\sigma} \in (0, 1)$ and $B_{ij} \equiv 1 - \beta_{ij}$, so that T_{ij} measures the freeness of trade from country i to country j and B_{ij} measures the strength of IPR protection in country j from the viewpoint of country i.

We focus on the case in which $\varphi_{ij}^L < \varphi_{ij}^X < \varphi_{ij}^I$ holds. To ensure that there exist some firms for each supply mode in equilibrium, we assume that $\{(1 - \underline{\chi}) + B_{ij}\delta(\bar{\chi} - 1)\}/(\bar{\chi} - 1) < T_{ij} < B_{ij}\delta/\underline{\chi}$ holds. The first inequality is required for the existence of exporting firms, while the second inequality is required for the existence of licensing firms. In order for all types of firms to exist in equilibrium, the freeness of trade must be sufficiently low in relation to the cost of licensing evaluated in terms of the fixed costs while taking the risk of imitation into account. At the same time, the freeness of trade must be sufficiently high in relation to the cost of FDI evaluated in terms of the fixed costs.

The cutoff productivities, which are obtained by solving Eqs. (13)–(16), are expressed as

$$(\varphi_j^D)^{\sigma-1} = \frac{c^\sigma f_j^D (\alpha P_j)^{1-\sigma}}{(1-\alpha)Y_j}, \tag{18}$$

$$(\varphi_{ij}^L)^{\sigma-1} = \frac{c^\sigma \underline{\chi} f_{ij}^X (\alpha P_j)^{1-\sigma}}{B_{ij}\delta(1-\alpha)Y_j}, \tag{19}$$

$$(\varphi_{ij}^X)^{\sigma-1} = \frac{c^\sigma (1-\underline{\chi}) f_{ij}^X (\alpha P_j)^{1-\sigma}}{(T_{ij}-B_{ij}\delta)(1-\alpha)Y_j}, \tag{20}$$

$$(\varphi_{ij}^I)^{\sigma-1} = \frac{c^\sigma (\bar{\chi}-1) f_{ij}^X (\alpha P_j)^{1-\sigma}}{(1-T_{ij})(1-\alpha)Y_j}. \tag{21}$$

Substituting (18)–(21) into (3) and solving for the price index in country j yields

$$P_j = \left(\frac{[(1-\alpha)Y_j]^{\frac{\sigma-k-1}{\sigma-1}}[k-(\sigma-1)]}{\alpha^k k c^{1-\frac{\sigma k}{\sigma-1}}[M_j \underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i \underline{\varphi}_i^k \Gamma_{ij}]} \right)^{\frac{1}{k}}, \tag{22}$$

where

$$\Gamma_{ij} = (f_{ij}^X)^{\frac{\sigma-k-1}{\sigma-1}} \left[(\frac{\underline{\chi}}{B_{ij}\delta})^{\frac{\sigma-k-1}{\sigma-1}} - (1-T_{ij})(\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta})^{\frac{\sigma-k-1}{\sigma-1}} + (\frac{\bar{\chi}-1}{1-T_{ij}})^{\frac{\sigma-k-1}{\sigma-1}} \right]. \tag{23}$$

Substituting Eq. (22) into (19) and (20) then yields

$$(\varphi_{ij}^L)^{\sigma-1} = \frac{c^\sigma \underline{\chi} f_{ij}^X}{\delta B_{ij}} \left(\frac{k[M_j \underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i \underline{\varphi}_i^k \Gamma_{ij}]}{(1-\alpha)Y_j[k-(\sigma-1)]} \right)^{\frac{\sigma-1}{k}},$$

$$(\varphi_{ij}^X)^{\sigma-1} = \frac{c^\sigma (1-\underline{\chi}) f_{ij}^X}{T_{ij}\delta B_{ij}} \left(\frac{k[M_j \underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i \underline{\varphi}_i^k \Gamma_{ij}]}{(1-\alpha)Y_j[k-(\sigma-1)]} \right)^{\frac{\sigma-1}{k}}.$$

Finally, under the assumption of (17) for $G(\varphi)$, from an individual licensing firm's revenue $r_{ij}^L(\varphi) = (c/\alpha P_j)^{1-\sigma} Y_j \varphi^{\sigma-1}$, bilateral flows of country i's licensing revenues from country j, RLF_{ij}, are given by

$$\begin{aligned} RLF_{ij} &= M_i(1-\alpha)(1-\beta_{ij})\delta \int_{\varphi_{ij}^L}^{\varphi_{ij}^X} r_{ij}^L(\varphi) dG(\varphi) \\ &= M_i(1-\alpha)B_{ij}\delta \int_{\varphi_{ij}^L}^{\varphi_{ij}^X} \left(\frac{c}{\alpha P_j}\right)^{1-\sigma} Y_j \varphi^{\sigma-1} k \underline{\varphi}_i^k \varphi^{-k-1} d\varphi \\ &= M_i B_{ij} \delta c^{1-\sigma} (\alpha P_j)^{\sigma-1} (1-\alpha) Y_j k \underline{\varphi}_i^k \frac{\left[(\varphi_{ij}^L)^{\sigma-k-1} - (\varphi_{ij}^X)^{\sigma-k-1}\right]}{k-(\sigma-1)} \\ &= A \underline{\varphi}_i^k M_i (Y_j^{\frac{1}{\sigma-1}} P_j)^k Z_{ij}, \end{aligned} \tag{24}$$

where

$$A = \frac{\delta c^{1-\frac{\sigma k}{\sigma-1}} k}{k-(\sigma-1)} \left[\alpha(1-\alpha)^{\frac{1}{\sigma-1}}\right]^k \tag{25}$$

and

$$Z_{ij} = (f_{ij}^X)^{\frac{\sigma-k-1}{\sigma-1}} B_{ij} \left[(\frac{\underline{\chi}}{B_{ij}\delta})^{\frac{\sigma-k-1}{\sigma-1}} - (\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta})^{\frac{\sigma-k-1}{\sigma-1}} \right]. \tag{26}$$

Note that the final line of Eq. (24) is derived by substituting Eqs. (19) and (20) into φ_{ij}^L and φ_{ij}^X in the third line of Eq. (24) and rearranging terms.

The system of equations of Eq. (24) with Eqs. (22), (23), (25), and (26) can be regarded as a structural gravity model for bilateral flows of licensing revenues.[18] That is, Eq. (24) indicates that bilateral flows of licensing revenues are increasing in both the market size of the destination country (Y_j) and that of the source country (Y_i), where the fact that bilateral licensing revenue flows are increasing in the size of the source country derives from the assumption that M_i is proportional to Y_i. As shown by Eq. (22), P_j represents the multilateral resistance term. Z_{ij} corresponds to the measure of "bilateral accessibility" of the country j market for country i firms in Head and Mayer's (2014) terminology with regard to standard gravity models for bilateral trade. As shown in the next subsection, RLF_{ij} is decreasing in f_{ij}^X, which is part of Z_{ij}. Thus, f_{ij}^X in our structural gravity model for bilateral flows of licensing revenues resembles the trade cost factor in standard gravity models for bilateral trade.

3.8 The impact of deep RTAs

In this subsection, we conduct a number of comparative statics analyses to investigate the impact of the establishment of deep RTAs on bilateral flows of licensing revenues.

In particular, we examine the effects of changes in f_{ij}^X, T_{ij}, and B_{ij} on bilateral flows of licensing revenues. We can see from Eqs. (24) and (26) that these variables affect licensing revenues through changes in P_j and Z_{ij}. Eq. (26) shows that Z_{ij} consists of three components: the inverse of the fixed costs of serving the foreign market ($(f_{ij}^X)^{\frac{\sigma-k-1}{\sigma-1}}$); the strength of IPR protection (B_{ij}); and the profitability of entry into licensing relative to other supply options ($\left[(\frac{\underline{\chi}}{B_{ij}\delta})^{\frac{\sigma-k-1}{\sigma-1}} - (\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta})^{\frac{\sigma-k-1}{\sigma-1}} \right]$).[19]

[18] It is also possible to derive a structural gravity model for bilateral flows of exports and FDI in a similar manner. See the Appendix.

[19] Other supply options in this case are not serving the foreign market and exporting. The interpretation of the third component is the following: the first term in the square brackets is the ratio of the difference in profits to the one in fixed costs between licensing and not serving the foreign market. If a firm chooses the licensing mode, it receives fraction $B_{ij}\delta$ of profits and incurs fixed costs (f_{ij}^X) multiplied by $\underline{\chi}$. By contrast, if the firm does not serve the market, profits and costs are both zero. Similarly, the second term in the square brackets is the ratio of the difference in profits to the one in fixed costs between exporting and licensing. A firm choosing the export mode earns profits multiplied by T_{ij} due to variable trade costs, while its fixed costs are multiplied by one. A licensing firm's profits and fixed costs are the same as those in the first case. Therefore, we can interpret the third component on the right-hand side of Eq. (26) as the difference between an index of the "difference in profitability between licensing and not serving the foreign market" ($(\underline{\chi}/B_{ij}\delta)^{\frac{\sigma-k-1}{\sigma-1}}$) and an index of the "difference in profitability between exporting and licensing"

An increase in each of these components improves the profitability of employing the licensing mode and hence expands the mass of licensing firms.

We first examine the effect of f_{ij}^X on RLF_{ij}. We obtain the following lemma:[20]

Lemma 1 *Differentiating Z_{ij} and P_j with respect to f_{ij}^X yields that*

$$\frac{\partial Z_{ij}}{\partial f_{ij}^X} < 0 \qquad \textit{and} \qquad \frac{\partial P_j}{\partial f_{ij}^X} > 0.$$

The intuition behind this result is as follows. A reduction in f_{ij}^X improves the profitability of serving the country j market regardless of the supply mode and promotes entry into the foreign market, which corresponds to an increase in Z_{ij}, so that the mass of licensing firms increases. On the other hand, the host country's market becomes more competitive because more foreign firms enter the market. Thus, the price index in country j, P_j, falls. The productivity of the average licenser from country i in the country j market decreases and hence the average revenue of licensing firms declines. From this lemma, we can see that there are two opposite effects on bilateral flows of licensing revenues. In the following proposition we show that the increase in the mass of licensing firms more than compensates for the fall in average licensing revenues, resulting in an increase in bilateral flows of licensing revenues.

Proposition 1 *A reduction in f_{ij}^X increases bilateral flows of country i's licensing revenues from country j.*

In our setting, a change in f_{ij}^X represents a change in the fixed costs for firms in country i to serve the country j market, regardless of the supply mode. Moreover, as discussed in the previous subsection, f_{ij}^X plays the role of the "trade cost factor" in our gravity model. Thus, a reduction in f_{ij}^X can be interpreted as an improvement in the OBA of the country j market for country i firms. In other words, this reduction can be regarded as the total impact of establishing deep RTAs. The reason is that since deep RTAs include various provisions, the establishment of a deep RTA will improve the OBA of the country j market to country i firms. Therefore, Proposition 1 implies that the establishment of a deep RTA increases bilateral flows of licensing revenues.

We next examine the effects of an increase in B_{ij} on RLF_{ij}. Such an increase means a strengthening of IPR protection in country j from the perspective of country i firms serving the country j market. We obtain the following results:

Lemma 2 *Differentiating Z_{ij} and P_j with respect to B_{ij} yields that*

$$\frac{\partial Z_{ij}}{\partial B_{ij}} > 0 \qquad \textit{and} \qquad \frac{\partial P_j}{\partial B_{ij}} < 0.$$

$(\{(1-\underline{\chi})/(T_{ij}-B_{ij}\delta)\}^{\frac{\sigma-k-1}{\sigma-1}})$. When the third component becomes larger, licensing is more attractive than not serving the market or exporting, and the number of firms entering the market increases.

[20]Proofs of lemmas and propositions are presented in Section A.2 in the Supplementary Appendix.

Lemma 2 suggests that, similar to a reduction in f_{ij}^X, a strengthening of IPR protection has two effects on bilateral flows of licensing revenues. First, as seen in Eq. (26), Z_{ij} consists of the product of B_{ij} and the index of the mass of licensing firms. Strengthening IPR protection increases the total license fees paid by licensees in j to licensers in i, which is captured by B_{ij}. At the same time, the range of firms that engage in licensing is expanded, increasing Z_{ij}. The increase in Z_{ij} increases bilateral flows of licensing revenues. Second, some firms switch their supply mode from exporting to licensing. They reduce their prices because they do not need to incur trade cost τ_{ij} anymore, although firms that switch their supply mode from FDI to exporting raise their prices. The former effect dominates, so that the price index in country j, P_j, decreases. The decrease in P_j reduces bilateral flows of licensing revenues. Thus, comparing these two effects, the following proposition is obtained.

Proposition 2 *An increase in B_{ij} increases bilateral flows of country i's licensing revenues from country j, RLF_{ij}. That is, $\partial RLF_{ij}/\partial B_{ij} > 0$ holds.*

This proposition suggests that a strengthening of IPR protection makes licensing more attractive. The intuition behind this proposition is as follows. An increase in B_{ij} has a direct positive impact on the revenue of each licensing firm, which strongly encourages firms to engage in licensing. Some firms that did not serve the country j market before the change start serving it through licensing after the increase in B_{ij}. Moreover, there are some other firms that switch their supply mode from exporting to licensing. Consequently, the mass of licensing firms increases. Moreover, this increase together with the direct increase in B_{ij} always dominates the negative effect through the reduction in the price index.

Next, we turn to the effect of an increase in T_{ij} on RLF_{ij}. In the context of RTAs, such an increase simply implies a reduction in tariffs. The increase can be interpreted as the impact of a shallow RTA. Similar to the effects of f_{ij}^X and B_{ij}, we consider the effects of T_{ij} on Z_{ij} and P_j separately. Given the definition of Z_{ij} (Eq. (26)), it is straightforward to show that

$$\frac{\partial Z_{ij}}{\partial T_{ij}} < 0.$$

Thus, an increase in the freeness of trade from country i to country j has the opposite effect of a strengthening of IPR protection. That is, an increase in T_{ij} changes each cutoff productivity so that the mass of licensing firms decreases. The effect of an increase in T_{ij} on P_j is not obvious and depends on the values of $k - (\sigma - 1)$ and T_{ij}. We can prove the following lemma:

Lemma 3 *(1) If $(T_{ij} - B_{ij}\delta)/(1 - T_{ij}) < \{k - (\sigma - 1)\}/(\sigma - 1)$ holds, it follows that $\partial P_j/\partial T_{ij} > 0$ holds. (2) If $(T_{ij} - B_{ij}\delta)/(1 - T_{ij}) > \{k - (\sigma - 1)\}/(\sigma - 1)$ holds, the sign of $\partial P_j/\partial T_{ij}$ depends on* *the degree of k, $(\sigma-1)$, and T_{ij}. Consider the following two cases: (i) $\{k-(\sigma-1)\}/(\sigma-1)=1$ (or $k=2(\sigma-1)$), and (ii) $\{k-(\sigma-1)\}/(\sigma-1)=2$ (or $k=3(\sigma-1)$). In case (i), $\partial P_j/\partial T_{ij}<0$ holds for $T_{ij}>\bar{T}^1_{ij}$. In case (ii), $\partial P_j/\partial T_{ij}<0$ holds for $T_{ij}>\bar{T}^2_{ij}$, where $\bar{T}^1_{ij}$ and $\bar{T}^2_{ij}$ are respectively defined as*

$$\bar{T}^1_{ij} \equiv \frac{1}{2}\left(1+B_{ij}\delta+\frac{1-\underline{\chi}}{\bar{\chi}-1}\right)$$

and

$$\bar{T}^2_{ij} \equiv \frac{1}{3}\left[1+2B_{ij}\delta-\left(\frac{1-\underline{\chi}}{\bar{\chi}-1}\right)^2+(1-\underline{\chi})^2\left(\frac{1}{(\bar{\chi}-1)^4}+\frac{4(1-B_{ij}\delta)}{(\bar{\chi}-1)^2(1-\underline{\chi})^2}+\frac{(1-B_{ij}\delta)^2}{(1-\underline{\chi})^4}\right)^{\frac{1}{2}}\right].$$

To understand the results in Lemma 3, it is important to examine how an increase in T_{ij} affects the prices of goods supplied via different supply modes. Firms continuing to export to country j reduce their prices due to the increase in T_{ij}. By contrast, those who switch their supply mode from either licensing or FDI to exporting *raise* their prices when T_{ij} increases. This is because these firms newly incur trade costs by switching their supply mode. However, it can be shown that if k is not very high relative to $(\sigma-1)$, the effect of the decrease in prices by continuing exporters dominates that of the increase in prices by switchers. In this case, the price index in country j, P_j, decreases.

In the latter half of Lemma 3, we take two particular values of $\{k-(\sigma-1)\}/(\sigma-1)$, namely, $\{k-(\sigma-1)\}/(\sigma-1)=1$ and $\{k-(\sigma-1)\}/(\sigma-1)=2$, as typical cases to satisfy $(T_{ij}-B_{ij}\delta)/(1-T_{ij})>\{k-(\sigma-1)\}/(\sigma-1)$. Crozet and Koenig (2010) provide estimates of $k-(\sigma-1)$ and σ by estimating the structural parameters of Chaney's (2008) gravity model using firm-level export data. Their estimates are that the mean and the median values of $\{k-(\sigma-1)\}/(\sigma-1)$ are 2.16 and 1.44, respectively. Based on their estimates, the parameter values of $\{k-(\sigma-1)\}/(\sigma-1)=1$ and $\{k-(\sigma-1)\}/(\sigma-1)=2$ seem plausible.

Thus, Lemma 3 implies that when the freeness of trade is sufficiently high, a further increase in freeness reduces bilateral flows of licensing revenues. In other words, a shallow RTA has a negative impact on bilateral licensing revenue flows.

When increases in B_{ij} and T_{ij} have the opposite effects on bilateral flows of licensing revenues, the net effect of a deep RTA that both strengthens IPR protection and reduces tariffs on RLF_{ij} depends on which effect dominates. That is, the initial levels of IPR protection and tariffs and the size of the increases in B_{ij} and T_{ij} affect the impact of a deep RTA.

Based on Lemma 3, we analyze the cross relationship between IPR protection and the freeness of trade by calculating the cross partial derivative. We obtain the following proposition:

Proposition 3 *Assume $\{k-(\sigma-1)\}/(\sigma-1)<(1-B_{ij}\delta)/\delta$. If $T_{ij}<\{(k-(\sigma-1))B_{ij}\delta\}/(\sigma-1)$ holds, it follows that $\partial^2 RLF_{ij}/\partial B_{ij}\partial T_{ij}>0$; otherwise, the sign is ambiguous.*

In this proposition, $\{k - (\sigma - 1)\}/(\sigma - 1) < (1 - B_{ij}\delta)/\delta$ holds if δ is relatively small. Moreover, this proposition implies that a strengthening of IPR protection and a reduction of tariffs are together conducive to bilateral flows of licensing revenues when trade costs are relatively high. In other words, a tariff reduction can enhance the positive effect of a strengthening of IPR protection on bilateral flows of licensing revenues when the freeness of trade is initially relatively low.

The predictions from our theoretical analysis can be summarized as follows:

Prediction 1: The establishment of a deep RTA increases bilateral flows of licensing revenues between member countries.

Prediction 2: A deep RTA with provisions that strengthen IPR protection increases bilateral flows of licensing revenues between member countries.

Prediction 3: The effect of establishing a shallow RTA on bilateral flows of licensing revenues is potentially negative.

In the next section, we empirically test these theoretical predictions.[21]

4 Empirical Framework and Data

4.1 Empirical framework

Our primary interest is to estimate the relationship between membership in shallow and deep RTAs and technology transfers among firms in the RTA member countries. Based on the model in Section 3.7, we derive our estimation equation.

The time-varying version of Eq. (24) is written as

$$RLF_{ijt} = A\underline{\varphi}_i^k M_{it}(Y_{jt}^{\frac{1}{\sigma-1}} P_{jt})^k Z_{ijt}, \tag{27}$$

where t denotes the year and Z_{ijt} is a time-varying version of Eq. (26), i.e.:

$$Z_{ijt} = (f_{ijt}^X)^{\frac{\sigma-k-1}{\sigma-1}} B_{ijt} \left[(\frac{\underline{\chi}}{B_{ijt}\delta})^{\frac{\sigma-k-1}{\sigma-1}} - (\frac{1-\underline{\chi}}{T_{ijt} - B_{ijt}\delta})^{\frac{\sigma-k-1}{\sigma-1}} \right].$$

Based on the results of the comparative statics in Section 3.8, we use a generic functional form to capture the elements in Z_{ijt}:

$$Z_{ijt} = \exp\left(\theta_1 LPI_{ijt} + \theta_2 IPR_{ijt} + \theta_3 OBA_{ijt}\right), \tag{28}$$

[21] As explained below, the data we use for the measurement of RLF_{ij} are the bilateral export values of royalties and license fees, which include payments between parent firms and their foreign subsidiaries. In our model, such payments are part of the profits from FDI. Given this, one could argue that part of $\pi_{ij}^I(\varphi)$ should be included in RLF_{ij}. However, doing so does not qualitatively change the results obtained in the lemmas and propositions. See the Appendix for details.

where $LPI_{ijt} = \left[(\frac{\chi}{B_{ijt}\delta})^{\frac{\sigma-k-1}{\sigma-1}} - (\frac{1-\chi}{T_{ijt}-B_{ijt}\delta})^{\frac{\sigma-k-1}{\sigma-1}}\right]$ denotes the licensing profitability index for licensing from country i to country i, $IPR_{ijt} = B_{ijt}$ is the degree of IPR protection in country j for firms from country i, and $OBA_{ijt} = (f_{ijt}^X)^{\frac{\sigma-k-1}{\sigma-1}}$ represents the overall bilateral accessibility of country j's market from country i. θ_1, θ_2, and θ_3 in (28) are the parameters to be estimated.

We define four dummy variables to represent the nature of the RTA between two countries. The first is $RTA\ dummy_{ijt}$, which is the usual RTA dummy and takes the value one if countries i and j both belong to the same RTA in year t, and zero otherwise. The next two dummies are $WTO_{TRIPS}^{plus-LE}\ dummy_{ijt}$ and $WTO_{IPR}^{X-LE}\ dummy_{ijt}$, which respectively take the value one if countries i and j both belong to the same RTA in year t and the legal enforceability (LE) indexes of the TRIPS provisions or the IPR provisions in the RTA take the value two, and zero otherwise.[22] The fourth dummy, $RTA_{-IPR}\ dummy_{ijt}$, takes the value one if countries i and j both belong to the same RTA in year t and the LE index of IPR provisions takes a value of less than or equal to one, and zero otherwise.

In addition, we define two indexes to measure the specific features of RTAs. The first, $Depth\ index_{ijt}$, measures the depth of RTAs. Limão (2016) proposes to measure the *depth* of RTAs using four categories of policy areas: (i) import tariffs; (ii) non-tariff barriers; (iii) behind the border policies; and (iv) other policies (see Table A.1 in the Supplementary Appendix). The category of import tariffs consists of two policy areas (FTA industrial goods and FTA agricultural goods), the non-tariff barriers category is composed of six policy areas (customs, export taxes, antidumping, countervailing measures, sanitary and phytosanitary measures, and technical barriers to trade), and five policy areas (state trading enterprises, competition policy, state aid, public procurement, and anti-corruption) compose the behind the border policies category. If an RTA covers all of the 13 policy areas in categories (i), (ii), and (iii) with an LE index value of two, the total points are 26. Our $Depth\ index_{ijt}$ is calculated by adding the LE index values for the 13 policy areas and dividing the total by 26, so that the depth of an RTA is measured on a scale from zero to one.

The second index to measure the specific features of RTAs that we use is $Tech\ index_{ijt}$, which measures the degree to which an RTA covers technology-related policy areas. Similar to the depth measure, Limão (2016) proposes to measure the *breadth* of RTAs in terms of five fields: (a) services; (b) technology; (c) investment/capital; (d) labor; and (e) non-economic policies (see Table A.1 in the Supplementary Appendix). Among these five fields, technology is the field that is most closely

[22]TRIPS provisions fall under what in the literature (see, e.g., Horn et al. (2010) and Hofmann et al. (2019)) are called the "WTO-plus" (or "WTO+") category, while IPR provisions fall under the "WTO-extra" (or "WTO-X") category. The LE index measures the degree of legal enforceability of each provision in terms of a scale from zero to two, taking zero if the provision is not legally enforceable, one if the provision is legally enforceable but explicitly excluded from dispute settlement provisions, and two if the provision is legally enforceable and included in dispute settlement provisions.

related to the focus of this study. The technology field consists of provisions concerning six policy areas: TRIPS; IPR; innovation policies; economic policy dialogue; information society; and research and technology. Similar to the $Depth\ index_{ijt}$, our $Tech\ index_{ijt}$ is calculated by adding the points of LE indexes of the six policy areas in the technology field and dividing the total by 12, so that it measures the degree of coverage on a scale from zero to one.

We use $WTO^{plus-LE}_{TRIPS}\ dummy_{ijt}$, $WTO^{X-LE}_{IPR}\ dummy_{ijt}$, and $Tech\ index_{ijt}$ as proxies for IPR_{ijt} in Eq. (28). Furthermore, we use $Depth\ index_{ijt}$ as a proxy for OBA_{ijt}, because deep integration improves the accessibility of the country j market from country i, regardless of the supply mode. Meanwhile, good proxies for LPI_{ijt} are difficult to find. Therefore, due to the lack of an alternative, we use $RTA\ dummy_{ijt}$ and $RTA_{-IPR}\ dummy_{ijt}$, since trade liberalization affects Z_{ij} only through LPI_{ijt}.

Substituting Eq. (28) with the proxies into Eq. (27) and representing the other terms in Eq. (27) by various fixed effects, we obtain the following equation for estimation:

$$\begin{aligned} RLF_{ijt} = &\exp\Big(\gamma_0 + \gamma_1 RTA\ dummy_{ij,t-1} + \gamma_2 WTO^{X-LE}_{IPR}\ dummy_{ij,t-1} + \gamma_3 Depth\ index_{ij,t-1} \\ &+\mu_{it} + \nu_{jt} + \zeta_{ij} + \epsilon_{ijt}\Big), \end{aligned} \tag{29}$$

where RLF_{ijt} represents the cross-border royalty and license fee revenues of country i (licenser) from country j (licensee) in year t. $RTA\ dummy_{ijt}$ may be replaced by $RTA_{-IPR}\ dummy_{ijt}$, while $WTO^{X-LE}_{IPR}\ dummy_{ijt}$ may be replaced by $WTO^{plus-LE}_{TRIPS}\ dummy_{ijt}$ or $Tech\ index_{ijt}$. Note that because most of the RTA variables are highly correlated with each other, we cannot include two or more RTA variables at the same time, except for the combination of $WTO^{X-LE}_{IPR}\ dummy_{ijt}$ and $RTA_{-IPR}\ dummy_{ijt}$. We use the combination of these two dummies to separate out the impact of RTAs without IPR provisions. In Eq. (29), a constant term (i.e., γ_0) and fixed effects, represented by μ_{it}, ν_{jt}, and ζ_{ij}, are also included, while ϵ_{ijt} is the error term. We include μ_{it} and ν_{jt} to capture multilateral resistances (Anderson and van Wincoop, 2003; Yotov et al., 2016) and ζ_{ij} to address the potential endogeneity of RTAs (Baier and Bergstrand, 2007; Yotov et al., 2016).

4.2 Description of data

This subsection describes the data we use in our empirical analysis. First, the data on cross-border flows of royalties and license fees are taken from the OECD database (OECD.Stat). We use data on bilateral charges for the use of intellectual property (or cross-border flows of royalties and license fees), which are part of the trade in services statistics from the balance of payments statistics,[23] for 49 countries, consisting of the OECD member countries and major emerging economies, covering the

[23] The data include industrial processes, computer software, trademarks, franchise fees, audiovisual and related products, and other intellectual property.

period 1995–2012.[24] The major emerging economies included consist of OECD accession candidates as well as the OECD's Key Partners. A list of countries in our dataset is provided in Table A.2 in the Supplementary Appendix.

Data on RTAs are taken from the database provided by Mario Larch (Egger and Larch, 2008),[25] while data on the content of RTAs are taken from the World Bank's website.[26] While the database provided by the World Bank includes 279 RTAs, we focus only on RTAs comprising at least two countries in our dataset as their signatories.[27] We end up with 63 RTAs in our sample. Table A.3 in the Supplementary Appendix provides a list of RTAs included in our sample . Further, we exclude country pairs with no bilateral flows of licensing revenues during our observation period. We then construct a panel of 2,104 country pairs spanning the period from 1995 to 2012.

Descriptive statistics and correlations of the variables are provided in Tables A.4 and A.5 in the Supplementary Appendix, respectively.

5 Empirical Results

5.1 Baseline estimation

We first estimate Eq. (29) using the PPML estimator with the time-varying source country (i.e., licenser) fixed effects, time-varying destination country (i.e., licensee) fixed effects, and source-destination-pair fixed effects, which is recommended in the gravity literature (Head and Mayer, 2014; Yotov et al., 2016). The results are reported in Table 2.

The estimated coefficients on the RTA variables in columns (1)–(5) are all positive and highly significant. These results suggest that RTAs have a positive impact on cross-border technology transfer through licensing. The magnitude of the impact depends on the nature of the RTA. The estimated coefficient on the RTA *dummy* in column (1) implies that RTAs increase bilateral flows of licensing revenues by 24.1% on average, regardless of the depth of the RTA.[28] Similarly, the estimated coefficient on the $WTO_{TRIPS}^{plus-LE}$ *dummy* in column (3) implies that RTAs with legally enforceable TRIPS

[24] The reason why our observation period ends in 2012 is that due to the update of the Balance of Payments Manual by the International Monetary Fund (IMF), the definitions of variables changed after 2012.

[25] URL: https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html.

[26] This dataset was originally provided by Horn et al. (2010) and extended by Hofmann et al. (2019). URL: https://datacatalog.worldbank.org/dataset/content-deep-trade-agreements. A new dataset on the content of deep trade agreements was released by the World Bank in 2020 (Mattoo et al., 2020), which includes more detailed information on the provisions in each policy area. However, for this study, we do not need to use this new dataset, so that we employ the data previously released by the World Bank.

[27] We include free trade areas, customs unions, and economic integration agreements but do not include partial scope agreements.

[28] $(e^{0.216} - 1) \times 100 \approx 24.1$.

Table 2: PPML Estimations: The Impact of Deep RTAs on Cross-border Licensing

	(1)	(2)	(3)	(4)	(5)	(6)
RTA dummy	0.216***					
	(0.081)					
Depth index		0.273***				
		(0.098)				
$WTO^{plus-LE}_{TRIPS}$ *dummy*			0.230***			
			(0.087)			
WTO^{X-LE}_{IPR} *dummy*				0.382***		0.355***
				(0.088)		(0.093)
Tech index					1.097***	
					(0.226)	
RTA_{-IPR} *dummy*						−0.038
						(0.105)
Source-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Destination-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Source-destination-pair FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	35,812	32,954	35,812	35,812	32,954	35,812

Notes: (a) The dependent variable is RLF_{ijt}. (b) Estimations were conducted using the Stata command `ppmlhdfe`. (c) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. (d) Standard errors clustered by country-pair are in parentheses. (e) The regressions include a constant term.

provisions increase bilateral flows of licensing revenues by 25.9% on average.[29] Thus, the inclusion of legally enforceable TRIPS provisions does not enhance the positive impact of RTAs on cross-border licensing much. By contrast, the estimate for the WTO^{X-LE}_{IPR} *dummy* in column (4) suggests that RTAs with legally enforceable IPR provisions increase bilateral flows of licensing revenues by 46.5% on average.[30] Therefore, the impact of an RTA on cross-border licensing is larger when the RTA includes legally enforceable IPR provisions than when it includes TRIPS provisions.

Moreover, the estimated coefficient on *Depth index* indicates that an increase in the index by one point is associated with an increase in bilateral licensing revenues by 1.2%.[31] On the other hand, the estimated coefficient on *Tech index* implies that an increase in this index by one point increases bilateral flows of licensing revenues by 16.6%.[32]

[29] $(e^{0.230} - 1) \times 100 \approx 25.9$.
[30] $(e^{0.382} - 1) \times 100 \approx 46.5$.
[31] $(e^{0.273} - 1) \times (1/26) \times 100 \approx 1.21$.
[32] $(e^{1.097} - 1) \times (1/12) \times 100 \approx 16.63$.

Finally, the results in column (6) show that when WTO_{IPR}^{X-LE} *dummy* and RTA_{-IPR} *dummy* are jointly included, the estimated coefficient on RTA_{-IPR} *dummy* is negative and statistically insignificant. This result suggests that a reduction in trade costs through an RTA by itself does not have a positive effect on bilateral flows of licensing revenues.

All of these results are consistent with the theoretical predictions presented in Section 3.8.

5.2 Robustness checks

To check the robustness of our baseline estimation results in the previous subsection, we conduct some additional estimations. We start by estimating Eq. (29) using the PPML estimator as above but this time exclude observations with extremely large values in the distribution of the dependent variable, since the dependent variable (i.e., bilateral flows of licensing revenues) is very skewed and the PPML estimator tends to over-weight observations with large values (Head and Mayer, 2014).

We select outliers according to the criterion based on the upper quartile and the interquartile range (IQR), which was proposed by Tukey (1977) and has been widely used in the literature (see, for example, Dekking et al. (2005)). The 75th and 25th quartiles in the distribution of data are called the upper and lower quartiles, respectively. Let $z(0.75)$ and $z(0.25)$ be the values of the upper and lower quartiles for a variable z, respectively. The IQR is then defined as $IQR = z(0.75) - z(0.25)$. Observations with the value of z beyond $z(0.75) + 1.5 \times IQR$ are detected as outliers (Dekking et al., 2005: 237). We apply this criterion to $\ln(RLF_{ijt})$ and find that eight observations are outliers in our data. Therefore, we exclude those outliers and re-estimate Eq. (29) using the PPML estimator.

The estimation results when excluding the observations with extremely large values are reported in Table 3. The results in Table 3 are qualitatively similar to those in Table 2.

Our second robustness check consists of employing the multinomial PML (MPML) estimator proposed by Eaton et al. (2013) and recommended by Head and Mayer (2014) as an estimation method for gravity models. To implement the MPML estimations, we calculate the share of bilateral flows of licensing revenues, $Share\_RLF_{ijt}$, by dividing the payments of royalties and license fees from country j to country i by the total cross-border payments of royalties and license fees by country j and use this as the dependent variable. The results are reported in Table 4. The size of the estimated coefficients is smaller than in Table 2, but otherwise the results remain qualitatively unchanged.

Finally, we employ the negative binomial estimator to address the issue of potential over-dispersion of the dependent variable.[33] The estimation results are reported in Table 5. Similar to the MPML estimations, the size of the estimated coefficients becomes smaller than in Table 2, but otherwise the results remain qualitatively unchanged.

[33] As shown in Table A.4, the standard deviation of RLF is much larger than its mean, which indicates the possibility of over-dispersion.

Table 3: Robustness Checks: PPML Estimations Excluding Outliers

	(1)	(2)	(3)	(4)	(5)	(6)
RTA dummy	0.236***					
	(0.081)					
Depth index		0.294***				
		(0.100)				
$WTO_{TRIPS}^{plus-LE}$ *dummy*			0.245***			
			(0.087)			
WTO_{IPR}^{X-LE} *dummy*				0.313***		0.341***
				(0.075)		(0.092)
Tech index					0.984***	
					(0.206)	
RTA_{-IPR} *dummy*						0.039
						(0.093)
Source-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Destination-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Source-destination-pair FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	35,804	32,946	35,804	35,804	32,946	35,804

Notes: (a) The dependent variable is RLF_{ijt}. (b) Estimations were conducted using the Stata command `ppmlhdfe`. (c) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. (d) Standard errors clustered by country-pair are in parentheses. (e) The regressions include a constant term.

Table 4: Robustness Checks: Multinomial PML Estimations

	(1)	(2)	(3)	(4)	(5)	(6)
RTA dummy	0.094*					
	(0.056)					
Depth index		0.126*				
		(0.067)				
$WTO^{plus-LE}_{TRIPS}$ *dummy*			0.107*			
			(0.058)			
WTO^{X-LE}_{IPR} *dummy*				0.092*		0.119*
				(0.051)		(0.062)
Tech index					0.317***	
					(0.121)	
RTA_{-IPR} *dummy*						0.054
						(0.065)
Source-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Destination-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Source-destination-pair FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	35,812	32,954	35,812	35,812	32,954	35,812

Notes: (a) The dependent variable is $Share\_RLF_{ijt}$. (b) Estimations were conducted using the Stata command `poisson`. (c) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. (d) Standard errors clustered by country-pair are in parentheses. (e) The regressions include a constant term.

Table 5: Robustness Checks: Negative Binomial Estimations

	(1)	(2)	(3)	(4)	(5)	(6)
RTA dummy	0.128**					
	(0.057)					
Depth index		0.168**				
		(0.072)				
$WTO^{plus-LE}_{TRIPS}$ *dummy*			0.157**			
			(0.061)			
WTO^{X-LE}_{IPR} *dummy*				0.112**		0.164**
				(0.051)		(0.064)
Tech index					0.341**	
					(0.142)	
RTA_{-IPR} *dummy*						0.087
						(0.062)
Source-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Destination-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Source-destination-pair FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	35,831	32,973	35,831	35,831	32,973	35,831

Notes: (a) The dependent variable is RLF_{ijt}. (b) Estimations were conducted using the Stata command `nbreg`. (c) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. (d) Standard errors clustered by country-pair are in parentheses. (e) The regressions include a constant term.

Given the above results of the robustness checks, we conclude that our findings in Section 5.1 are generally robust.

6 Conclusions

In this study, we analyzed the impact of deep RTAs on bilateral flows of licensing revenues. We started by presenting our motivating evidence that cross-border licensing is governed by "gravity" and then developed a trade model in which heterogeneous firms in a monopolistically competitive industry choose to supply their goods to foreign markets through export, FDI, or licensing. From this model, we derived a structural gravity equation for cross-border licensing revenues. We then conducted comparative statics analysis to show the effects of changes in the fixed costs of serving the destination country, the freeness of trade, and the strength of IPR protection on cross-border flows of licensing revenues.

We next estimated the gravity model for licensing and examined how different types of RTAs affect bilateral flows of licensing revenues. We measured the nature of RTAs using various dummy variables and indexes.

Our findings supported the predictions of the model. Specifically, we found that improved bilateral access through deep RTAs as well as stronger IPR protection through RTAs with legally enforceable IPR provisions or technology-related provisions increases cross-border flows of licensing revenues. By contrast, shallow RTAs without IPR provisions do not increase cross-border licensing revenues. Further, we checked the robustness of our results by estimating the model excluding observations with extremely large values and employing the MPML and negative binomial estimators. The results of those exercises implied that our findings are robust.

The results obtained in this study have the following policy implication. Deep RTAs with legally enforceable provisions in technology-related areas are, as expected, more conducive to cross-border licensing than RTAs without such provisions. Licensing is an important mode of supplying foreign markets, particularly for large multinational enterprises (MNEs) holding a large number of patents and other intellectual property, though those MNEs could choose other supply modes such as export or FDI. Firms acting as licensees in foreign markets benefit from such cross-border licensing business. Furthermore, consumers also benefit greatly from the fact that firms engage in cross-border licensing, since some of the products produced under licensing otherwise would not be available to them. Therefore, from a global welfare perspective, it is desirable for governments to pursue deep RTAs with legally enforceable IPR protection and other technology-related provisions in order to facilitate cross-border licensing.

Appendix Derivation of the Structural Gravity Model for Bilateral Flows of Exports and FDI

In this appendix, we derive the structural gravity model for bilateral flows of exports and FDI.

First, using an individual exporting firm's revenue in country i from serving the country j market, $r_{ij}^X(\varphi) = (\tau_{ij}c/\alpha\varphi P_j)^{1-\sigma}Y_j$, bilateral flows of country i's exports to country j, EX_{ij}, are given by

$$\begin{aligned}
EX_{ij} &= M_i \int_{\varphi_{ij}^X}^{\varphi_{ij}^I} (1-\alpha) \left(\frac{\tau_{ij}c}{\alpha\varphi P_j} \right)^{1-\sigma} Y_j dG(\varphi) \\
&= M_i c^{1-\sigma} T_{ij} (\alpha P_j)^{\sigma-1} (1-\alpha) Y_j k \underline{\varphi}_i^k \frac{\left[(\varphi_{ij}^X)^{\sigma-k-1} - (\varphi_{ij}^I)^{\sigma-k-1} \right]}{k-(\sigma-1)} \\
&= (A/\delta) \underline{\varphi}_i^k M_i (Y_j^{\frac{1}{\sigma-1}} P_j)^k Q_{ij},
\end{aligned}$$

where

$$Q_{ij} = (f_{ij}^X)^{\frac{\sigma-k-1}{\sigma-1}} T_{ij} \left[\left(\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta} \right)^{\frac{\sigma-k-1}{\sigma-1}} - \left(\frac{\bar{\chi}-1}{1-T_{ij}} \right)^{\frac{\sigma-k-1}{\sigma-1}} \right].$$

It can be shown that $\partial Q_{ij}/\partial B_{ij} < 0$ and $\partial Q_{ij}/\partial T_{ij} > 0$ hold. Whereas a strengthening of IPR protection decreases bilateral flows of exports, the impact of a tariff reduction on export flows is ambiguous because the sign of $\partial P_j/\partial T_{ij}$ depends on the parameters.

We next derive the structural gravity model for bilateral FDI flows. Using an individual firm's revenue from serving the country j market through FDI, $r_{ij}^I(\varphi) = (c/\alpha\varphi P_j)^{1-\sigma}Y_j$, bilateral flows of country i's FDI to country j, FDI_{ij}, are given by

$$\begin{aligned}
FDI_{ij} &= M_i \int_{\varphi_{ij}^I}^{\infty} (1-\alpha) \left(\frac{c}{\alpha\varphi P_j} \right)^{1-\sigma} Y_j dG(\varphi) \\
&= M_i c^{1-\sigma} (\alpha P_j)^{\sigma-1} (1-\alpha) Y_j k \underline{\varphi}_i^k \frac{(\varphi_{ij}^I)^{\sigma-k-1}}{k-(\sigma-1)} \\
&= (A/\delta) \underline{\varphi}_i^k M_i (Y_j^{\frac{1}{\sigma-1}} P_j)^k X_{ij},
\end{aligned}$$

where

$$X_{ij} \equiv \left(\frac{(\bar{\chi}-1) f_{ij}^X}{1-T_{ij}} \right)^{\frac{\sigma-k-1}{\sigma-1}}.$$

It immediately follows that $\partial X_{ij}/\partial T_{ij} < 0$ holds. Therefore, the signs of the comparative statics regarding FDI_{ij} coincide with those regarding RLF_{ij}. Consequently, even when we treat the sum of RLF_{ij} and FDI_{ij} as our outcome variable, the comparative statics results in Section 3.8 do not qualitatively change.

References

Anderson, James E. (2011), 'The gravity model', *Annual Review of Economics* **3(1)**, 133–160.

Anderson, James E., Mario Larch, and Yoto V. Yotov (2019), 'Trade and investment in the global economy: A multi-country dynamic analysis', *European Economic Review* **120(C)**, 103311.

Anderson, James E., and Eric van Wincoop (2003), 'Gravity with gravitas: A solution to the border puzzle', *American Economic Review* **93(1)**, 170–192.

Antràs, Pol, and Stephen R. Yeaple (2014), 'Multinational firms and the structure of international trade', in Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, eds., *Handbook of International Economics* Vol. 4. Amsterdam: Elsevier, 55–130.

Baier, Scott L., and Jeffrey H. Bergstrand (2007), 'Do free trade agreements actually increase members' international trade?', *Journal of International Economics* **71(1)**, 72–95.

Baldwin, Richard (2011), '21st century regionalism: Filling the gap between 21st century trade and 20th century trade rules', World Trade Organization Staff Working Paper ERSD–2011–08.

Branstetter, Lee G., Raymond Fisman, and C. Fritz Foley (2006), 'Do stronger intellectual property rights increase international technology transfer? Empirical evidence from U.S. firm-level panel data', *Quarterly Journal of Economics* **121(1)**, 321–349.

Chaney, Thomas (2008), 'Distorted gravity: The intensive and extensive margins of international trade', *American Economic Review* **98(4)**, 1707–1721.

Crozet, Matthieu, and Pamina Koenig (2010), 'Structural gravity equations with intensive and extensive margins', *Canadian Journal of Economics* **43(1)**, 41–62.

Dekking, Frederik Michael, Cornelis Kraaikamp, Hendrik Paul Lopuhaä, and Ludolf Erwin Meester (2005), *A Modern Introduction to Probability and Statistics: Understanding Why and How.* London: Springer-Verlag.

Dür, Andreas, Leonardo Baccini, and Manfred Elsig (2014), 'The design of international trade agreements: Introducing a new dataset', *Review of International Organizations* **9(3)**, 353–375.

Eaton, Jonathan, and Samuel Kortum (2018), 'Trade in goods and trade in services', in Lily Yan Ing and Miaojie Yu, eds., *World Trade Evolution: Growth, Productivity and Employment.* Taylor & Francis, 82–125.

Eaton, Jonathan, Samuel S. Kortum, and Sebastian Sotelo (2013), 'International trade: Linking micro and macro', in Daron Acemoglu, Manuel Arellano, and Eddie Dekel, eds., *Advances in*

Economics and Econometrics, Tenth World Congress, Volume II: Applied Economics. Cambridge University Press, 329–370.

Egger, Peter H., and Mario Larch (2008), 'Interdependent preferential trade agreement memberships: An empirical analysis', *Journal of International Economics* **76(2)**, 384–399.

Ethier, Wilfred J., and James R. Markusen (1996), 'Multinational firms, technology diffusion and trade', *Journal of International Economics* **41(1/2)**, 1–28.

Falley, Thibault (2015), 'Structural gravity and fixed effects', *Journal of International Economics* **97(1)**, 76–85.

Grossman, Gene M., Phillip McCalman, and Robert W. Staiger (2021), 'The "new" economics of trade agreements: From trade liberalization to regulatory convergence?', *Econometrica* **89(1)**, 215–249.

Head, Keith, and Thierry Mayer (2014), 'Gravity equations: Workhorse, toolkit, and cookbook', in Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, eds., *Handbook of International Economics*, Vol. 4. Amsterdam: Elsevier, 131–195.

Head, Keith, and John Ries (2008), 'FDI as an outcome of the market for corporate control: Theory and evidence', *Journal of International Economics* **74(1)**, 2–20.

Helpman, Elhanan, Marc J. Melitz, and Yona Rubinstein (2008), 'Estimating trade flows: Trading partners and trading volumes', *Quarterly Journal of Economics* **123(2)**, 441–487.

Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple (2004), 'Export versus FDI with heterogeneous firms', *American Economic Review* **94(1)**, 300–316.

Hofmann, Claudia, Alberto Osnago, and Michele Ruta (2019), 'The content of prefential trade agreements', *World Trade Review* **18(3)**, 365–398.

Horn, Henrik, Petros C. Mavroidis, and André Sapir (2010), 'Beyond the WTO? An anatomy of EU and US preferential trade agreements', *The World Economy* **33(11)**, 1565–1588.

Horstmann, Ignatius, and James R. Markusen (1987), ' Licensing versus direct investment: A model of internalization by the multinational enterprise', *Canadian Journal of Economics* **20(3)**, 464–481.

Ivus, Olena (2010), 'Do stronger patent rights raise high-tech exports to the developing world?', *Journal of International Economics* **81(1)**, 38–47.

Ivus, Olena (2011), 'Trade-related intellectual property rights: Industry variation and technology diffusion', *Canadian Journal of Economics* **44(1)**, 201–226.

Ivus, Olena, Walter G. Park, and Kamal Saggi (2017), 'Patent protection and the composition of multinational activity: Evidence from US multinational firms', *Journal of International Business Studies* **48(7)**, 808–836.

Jinji, Naoto, Xingyuan Zhang, and Shoji Haruna (2019), 'Do deeper regional trade agreements enhance international technology spillovers?', *The World Economy* **42(8)**, 2326–2363.

Kleinert, Jörn, and Farid Toubal (2010), 'Gravity for FDI', *Review of International Economics* **18(1)**, 1–13.

Limão, Nuno (2016), 'Preferential trade agreements', in Kyle Bagwell and Robert W. Staiger, eds., *Handbook of Commercial Policy, Vol. 1B*. Amsterdam: Elsevier, 279–367.

Maggi, Giovanni, and Ralph Ossa (2020), 'Are trade agreements good for you?', Working Paper No. 27252, National Bureau of Economic Research.

Maggi, Giovanni, and Ralph Ossa (2021), 'The political economy of deep integration', *Annual Review of Economics*, forthcoming.

Markusen, James R., and Yiqing Xie (2017), 'Productivity differences among unaffiliated domestic firms, licensees and foreign subsidiaries', Working Paper, University of Colorado at Boulder.

Mattoo, Aaditya, Alen Mulabdic, and Michele Ruta (2017), 'Trade creation and trade diversion in deep agreements', World Bank Policy Research Working Paper No. 8206.

Mattoo, Aaditya, Nadia Rocha, and Michele Ruta, eds. (2020), *Handbook of Deep Trade Agreements*. World Bank

Mayer, Thierry, and Soledad Zignago (2011), 'Notes on CEPII's distances measures: The GeoDist database', CEPII Working Paper 2011–25.

Moore, Christopher M., and Grete Birtwistle (2004), 'The Burberry business model: Creating an international luxury fashion brand', *International Journal of Retail and Distribution Management* **32(8)**, 412–422.

Nagaoka, Sadao (2009), 'Does strong patent protection facilitate international technology transfer? Some evidence from licensing contracts of Japanese firms', *Journal of Technology Transfer* **34(2)**, 128–144.

Naghavi, Alireza (2007), 'Strategic intellectual property rights policy and North-South technology transfer', *Review of World Economics* **143(1)**, 55–78.

Naghavi, Alireza, Shin-Kun Peng, and Yingyi Tsai (2017), 'Relationship-specific investments and intellectual property rights enforcement with heterogeneous suppliers', *Review of International Economics* **25(3)**, 626–648.

Orefice, Gianluca, and Nadia Rocha (2014), 'Deep integration and production networks: An empirical analysis', *The World Economy* **37(1)**, 106–36.

Osnago, Alberto, Nadia Rocha, and Michele Ruta (2016), 'Do deep trade agreements boost vertical FDI?', *World Bank Economic Review* **30**, S119–S125.

Santos Silva, J.M.C. and Silvana Tenreyro (2006), 'The log of gravity', *Review of Economics and Statistics* **88(4)**, 641–658.

Santos Silva, J.M.C. and Silvana Tenreyro (2011), 'Further simulation evidence on the performance of the Poisson pseudo-maximum likelihood estimator', *Economics Letters* **112(2)**, 220–222.

Smith, Pamela J. (2001), 'How do foreign patent rights affect US exports, affiliate sales, and licenses?', *Journal of International Economics* **55(2)**, 411–439.

Tanaka, Hitoshi, Tatsuro Iwaisako, and Koichi Futagami (2007), 'Dynamic analysis of innovation and international transfer of technology through licensing', *Journal of International Economics* **73(1)**, 189–212.

Tukey, John W. (1977), *Exploratory Data Analysis.* Reading, Mass.: Addison-Wesley.

Yang, Guifang, and Keith E. Maskus (2001a), 'Intellectual property rights and licensing: An econometric investigation', *Weltwirtschaftliches Archiv* **137(1)**, 58–79.

Yang, Guifang, and Keith E. Maskus (2001b), 'Intellectual property rights, licensing, and innovation in an endogenous product-cycle model', *Journal of International Economics* **53(1)**, 169–187.

Yang, Lei and Keith E. Maskus (2009), 'Intellectual property rights, technology transfer and exports in developing countries', *Journal of Development Economics* **90(2)**, 231–236.

Yasar, Mahmut, and Catherine J. Morrison Paul (2007), 'International linkages and productivity at the plant level: Foreign direct investment, exports, imports and licensing', *Journal of International Economics* **71(2)**, 373–388.

Yotov, Yoto V., Robert Piermartini, José-Antonio Monteiro, and Mario Larch (2016), *An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model, Online Revised Version.* World Trade Organization.

Supplementary Appendix to

"Gravity for Cross-border Licensing and the Impact of Deep Trade Agreements: Theory and Evidence"

Naoto JINJI Yukiko SAWADA
Xingyuan ZHANG Shoji HARUNA

A.1 Endogenous Determination of License Fees through Nash Bargaining

We consider the case in which a potential licenser and a potential licensee negotiate over the value of δ through Nash bargaining. In the negotiation, the two parties decide the allocation of the expected revenue from licensing, or $(1-\beta_{ij})c^{1-\sigma}/(\alpha\varphi P_j)^{1-\sigma}Y_j$. Note that we assume that the fixed cost of licensing, cf_{ij}^L, is entirely borne by the licenser. In order to analyze the Nash bargaining outcome, we need to identify the disagreement point, i.e., the outcome when the negotiation breaks down. If the negotiation breaks down, the potential licensee becomes a potential imitator. We assume that the potential licensee with productivity level φ' can only imitate a variety produced by a firm with productivity level $\varphi \leq \varphi'$. On the other hand, when the negotiation breaks down, the potential licenser has two options, depending on its productivity level. Define $\varphi_{ij}^{X_0}$ as the cutoff productivity that satisfies

$$\pi_{ij}^X(\varphi_{ij}^{X_0}) = 0.$$

That is, a firm with a productivity level of $\varphi_{ij}^{X_0}$ in country i earns zero profits from exporting to the country j market. Thus, a potential licenser with a productivity level of φ in the range of $\varphi_{ij}^L < \varphi < \varphi_{ij}^{X_0}$ exits from the country j market when the negotiation breaks down. By contrast, a potential licenser with productivity $\varphi_{ij}^{X_0} \leq \varphi < \varphi_{ij}^X$ exports to country j when the negotiation breaks down.

As assumed in Section 3.3, a product can be imitated only if the product is licensed. Thus, no potential licensee in country j can imitate the product when the negotiation for licensing breaks down, since products that potential licensees are able to imitate are either not supplied to the country j market or are exported from country i. This implies that the payoff for a potential licensee at the disagreement point is zero, regardless of the productivity level of the potential licenser in the negotiation.

For a potential licenser with productivity $\varphi_{ij}^L < \varphi < \varphi_{ij}^{X_0}$, the payoff at the disagreement point is zero because it exits from the country j market if the negotiation breaks down. By contrast, for a potential licenser with productivity $\varphi_{ij}^{X_0} \leq \varphi < \varphi_{ij}^X$, the payoff at the disagreement point is the revenue from exporting, or $\{(\tau_{ij}c)/(\alpha\varphi P_j)\}^{1-\sigma}Y_j$.

Therefore, the Nash bargaining outcome from the negotiation between a potential licenser with productivity $\varphi_{ij}^L < \varphi < \varphi_{ij}^{X_0}$ and a potential licensee is the solution that maximizes the following Nash product:

$$\left[(1-\delta)(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\right]\times\left[\delta(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\right]$$

subject to

$$(1-\delta)(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\geq 0 \qquad \text{and} \qquad \delta(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\geq 0$$

by choosing $\delta\in(0,1)$. In this case, it is easy to obtain the Nash bargaining outcome, which is $\delta^*=1/2$.

On the other hand, the Nash bargaining outcome from the negotiation between a potential licenser with productivity $\varphi_{ij}^{X_0}\leq\varphi<\varphi_{ij}^{X}$ and a potential licensee is the solution that maximizes the following Nash product:

$$\left[(1-\delta)(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\right]\times\left[\delta(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j-\left(\frac{\tau_{ij}c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\right]$$

subject to

$$(1-\delta)(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\geq 0 \qquad \text{and} \qquad \delta(1-\beta_{ij})\left(\frac{c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j\geq\left(\frac{\tau_{ij}c}{\alpha\varphi P_j}\right)^{1-\sigma}Y_j$$

by choosing $\delta\in(0,1)$.

From the first-order condition, we obtain

$$\delta^{**}=\frac{1}{2}\left(1+\frac{(\tau_{ij})^{1-\sigma}}{1-\beta_{ij}}\right)$$

as the Nash bargaining solution in this case.

Note that substituting the Nash bargaining outcomes δ^* and δ^{**} into the system of equations for bilateral flows of licensing revenues RLF_{ij} (Eqs. (22)–(26)) does not qualitatively change the comparative statics results in Section 3.8.

A.2 Proofs of Lemmas and Propositions

Proof of Lemma 1.

Differentiating (26) and (22) with respect to f_{ij}^X yields

$$\frac{\partial Z_{ij}}{\partial f_{ij}^X}=-\frac{k-(\sigma-1)}{\sigma-1}(f_{ij}^X)^{-1}Z_{ij}<0, \tag{A.1}$$

and

$$\frac{\partial P_j}{\partial f_{ij}^X}=-\frac{1}{k}\frac{M_j\underline{\varphi}_j^kP_j^{\frac{1}{k}}}{\left(M_j\underline{\varphi}_j^k(f_j^D)^{\frac{\sigma-k-1}{\sigma-1}}+\sum_{i\neq j}M_i\underline{\varphi}_j^k\Gamma_{ij}\right)}\frac{\partial\Gamma_{ij}}{\partial f_{ij}^X}. \tag{A.2}$$

With regard to the sign of (A.2), $\partial P_j/\partial f_{ij}^X>0$ holds because

$$\frac{\partial\Gamma_{ij}}{\partial f_{ij}^X}=-\frac{k-(\sigma-1)}{\sigma-1}(f_{ij}^X)^{-1}\Gamma_{ij}<0. \tag{A.3}$$

∎

Proof of Proposition 1.

Substituting (26) and (23) into (24) and differentiating with respect to f_{ij}^X yields

$$
\begin{aligned}
\frac{\partial RLF_{ij}}{\partial f_{ij}^X} &= \frac{\delta \underline{\varphi}_i^k M_i(1-\alpha)Y_j}{\left(M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_j^k\Gamma_{ij}\right)^2}\left[\left(M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}\right)\frac{\partial Z_{ij}}{\partial f_{ij}^X} - Z_{ij}M_i\underline{\varphi}_i^k\frac{\partial \Gamma_{ij}}{\partial f_{ij}^X}\right] \\
&< \frac{\delta \underline{\varphi}_i^k M_i(1-\alpha)Y_j}{\left(M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}\right)^2}\left[M_i\underline{\varphi}_i^k\Gamma_{ij}\frac{\partial Z_{ij}}{\partial f_{ij}^X} - Z_{ij}M_i\underline{\varphi}_i^k\frac{\partial \Gamma_{ij}}{\partial f_{ij}^X}\right].
\end{aligned}
$$

This inequality holds because we assume $\underline{\varphi}_i^k > 0, M_i > 0$, and there are $J(\geq 2)$ countries in our model. The terms in the square brackets in the second line become

$$
M_i\underline{\varphi}_i^k\Gamma_{ij}\frac{\partial Z_{ij}}{\partial f_{ij}^X} - Z_{ij}M_i\underline{\varphi}_i^k\frac{\partial \Gamma_{ij}}{\partial f_{ij}^X} = 0
$$

because (A.1) and (A.3). Therefore, $\frac{\partial RLF_{ij}}{\partial f_{ij}^X} < 0$ is satisfied. ∎

Proof of Lemma 2. Differentiating Z_{ij} and P_j with respect to B_{ij} yields

$$
\frac{\partial Z_{ij}}{\partial B_{ij}} = \frac{f_{ij}^{X\,\frac{\sigma-k-1}{\sigma-1}}}{\sigma-1}\left[k\left(\frac{\underline{\chi}}{B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}} + \frac{kB_{ij}\delta-(\sigma-1)T_{ij}}{T_{ij}-B_{ij}\delta}\left(\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}}\right] > 0,
$$

$$
\begin{aligned}
\frac{\partial P_j}{\partial B_{ij}} =& - P_j\left[M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_j^k\Gamma_{ij}\right]^{-1}\frac{M_i\underline{\varphi}_i^k(k-(\sigma-1))}{k(\sigma-1)} \\
&\times f_{ij}^{X\,\frac{\sigma-k-1}{\sigma-1}}\left[\left(\frac{\underline{\chi}}{B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}}\frac{1}{B_{ij}} + \left(\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}}\frac{(1-T_{ij})\delta}{T_{ij}-B_{ij}\delta}\right] < 0.
\end{aligned}
$$ ∎

Proof of Proposition 2. We consider the effect of a strengthening of IPR protection on total licensing revenue. Differentiating RLF_{ij} with respect to B_{ij} yields

$$
\begin{aligned}
\frac{\partial RLF_{ij}}{\partial B_{ij}} &= A\underline{\varphi}_i^k M_i Y_j^{\frac{k}{\sigma-1}} kP_j^{k-1}\left(Z_{ij}\frac{\partial P_j}{\partial B_{ij}} + P_j\frac{\partial Z_{ij}}{\partial B_{ij}}\right) \\
&= \frac{\delta k\underline{\varphi}_i^k M_i(1-\alpha)Y_j}{M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}}\left[-\frac{M_i\underline{\varphi}_i^k Z_{ij}}{M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}}\frac{\partial \Gamma_{ij}}{\partial B_{ij}} + \frac{\partial Z_{ij}}{\partial B_{ij}}\right] \\
&\geq \frac{B_{ij}[M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}] - Z_{ij}M_i\underline{\varphi}_i^k}{M_j\underline{\varphi}_j^k (f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}}\frac{k-(\sigma-1)}{\sigma-1} \\
&\times f_{ij}^{X\,\frac{\sigma-k-1}{\sigma-1}}\left[\left(\frac{\underline{\chi}}{B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}}\frac{1}{B_{ij}} + \left(\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}}\frac{\delta}{T_{ij}-B_{ij}\delta}\right] > 0
\end{aligned}
$$

because

$$B_{ij}[M_j\underline{\varphi}_j^k(f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + \sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}] - Z_{ij}M_i\underline{\varphi}_i^k$$

$$\geq B_{ij}M_j\underline{\varphi}_j^k(f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + M_i\underline{\varphi}_i^k(B_{ij}\Gamma_{ij} - Z_{ij})$$

$$= B_{ij}\left[M_j\underline{\varphi}_j^k(f_j^D)^{\frac{\sigma-k-1}{\sigma-1}} + M_i\underline{\varphi}_i^k f_{ij}^{X\,\frac{\sigma-k-1}{\sigma-1}}\left(T_{ij}\left(\frac{1-\underline{\chi}}{T_{ij}-B_{ij}\delta}\right)^{\frac{k-(\sigma-1)}{\sigma-1}} + \left(\frac{\bar{\chi}-1}{1-T_{ij}}\right)^{\frac{k-(\sigma-1)}{\sigma-1}}\right)\right] > 0.$$

∎

Proof of Lemma 3. Differentiating P_j with respect to T_{ij} yields the following:

$$\frac{\partial P_j}{\partial T_{ij}} = -\left(M_j\underline{\varphi}_j^k(f_j^D)^{\frac{k-(\sigma-1)}{\sigma-1}} + B_{ij}\sum_{i\neq j} M_i\underline{\varphi}_i^k\Gamma_{ij}\right)^{-1} P_j M_i\underline{\varphi}_i^k\frac{\partial\Gamma_{ij}}{\partial T_{ij}}.$$

Calculating $\partial\Gamma_{ij}/\partial T_{ij}$, we have

$$\frac{\partial\Gamma_{ij}}{\partial T_{ij}} = \left(\frac{(1-\underline{\chi})f_{ij}^X}{T_{ij}-B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}}\left[1 - \frac{1-T_{ij}}{T_{ij}-B_{ij}\delta}\frac{k-(\sigma-1)}{\sigma-1}\right] - \frac{k-(\sigma-1)}{(\sigma-1)(1-T_{ij})}\left(\frac{(\bar{\chi}-1)f_{ij}^X}{1-T_{ij}}\right)^{\frac{\sigma-k-1}{\sigma-1}}.$$

If $T_{ij} < 1 - \frac{\sigma-1}{k}(1-B_{ij}\delta)$, $\frac{\partial\Gamma_{ij}}{\partial T_{ij}}$ is negative. Otherwise, it depends on the degree of $\frac{k-(\sigma-1)}{\sigma-1}$. In what follows we therefore consider two cases. First, we consider the case in which $\frac{k-(\sigma-1)}{\sigma-1} = 1$. In this case,

$$\frac{\partial\Gamma_{ij}}{\partial T_{ij}} = \frac{1}{(1-\underline{\chi})f_{ij}^X}[2T_{ij} - (1+B_{ij}\delta)] - \frac{1}{(\bar{\chi}-1)f_{ij}^X} \ > \ (<)\ 0$$

is satisfied if and only if

$$T_{ij} \ > \ (<)\ \bar{T}_{ij}^1 \equiv \frac{1}{2}\left(1 + B_{ij}\delta + \frac{1-\underline{\chi}}{\bar{\chi}-1}\right).$$

Second, we consider the case in which $\frac{k-(\sigma-1)}{\sigma-1} = 2$. For $\frac{B_{ij}(B_{ij}\delta+2)}{2} < \left(\frac{1-\underline{\chi}}{\bar{\chi}-1}\right)^2$, we obtain

$$\frac{\partial\Gamma_{ij}}{\partial T_{ij}} = \frac{1}{[(1-\underline{\chi})f_{ij}^X]^2}[3(T_{ij})^2 - (4B_{ij}\delta+2)T_{ij} + B_{ij}\delta(B_{ij}\delta+2)] - \frac{2(1-T_{ij})}{[(\bar{\chi}-1)f_{ij}^X]^2} \ > \ (<)\ 0$$

if and only if

$$T_{ij} \ > \ (<)\ \bar{T}_{ij}^2 \equiv \frac{1}{3}\left[1 + 2B_{ij}\delta - \left(\frac{1-\underline{\chi}}{\bar{\chi}-1}\right)^2 + (1-\underline{\chi})^2\left(\frac{1}{(\bar{\chi}-1)^4} + \frac{4(1-B_{ij}\delta)}{(\bar{\chi}-1)^2(1-\underline{\chi})^2} + \frac{(1-B_{ij}\delta)^2}{(1-\underline{\chi})^4}\right)^{\frac{1}{2}}\right]. \quad ∎$$

Proof of Proposition 3. Differentiating $\frac{\partial RLF_{ij}}{\partial B_{ij}}$ with respect to T_{ij} yields

$$\frac{\partial^2 RLF_{ij}}{\partial B_{ij}\partial T_{ij}} = P_j^{-1}(k-1)\frac{\partial P_j}{\partial T_{ij}}\frac{\partial RLF_{ij}}{\partial B_{ij}} + A\underline{\varphi}_i^k M_i Y_j^{\frac{k}{\sigma-1}} kP_j\left(\frac{\partial Z_{ij}}{\partial T_{ij}}\frac{\partial P_j}{\partial B_{ij}} + Z_{ij}\frac{\partial^2 P_j}{\partial B_{ij}\partial T_{ij}} + \frac{\partial P_j}{\partial T_{ij}}\frac{\partial Z_{ij}}{\partial B_{ij}} + P_j\frac{\partial^2 Z_{ij}}{\partial B_{ij}\partial T_{ij}}\right)$$

From Lemma 2, $\frac{\partial Z_{ij}}{\partial B_{ij}} > 0$ and $\frac{\partial P_j}{\partial B_{ij}} < 0$ hold. As discussed in the main text, $\frac{\partial Z_{ij}}{\partial T_{ij}} < 0$ holds. Assume that $1 - \frac{(\sigma-1)(1-B_{ij}\delta)}{\delta(k-(\sigma-1))} < 0$. It can then be shown that $\frac{\partial^2 P_j}{\partial B_{ij}\partial T_{ij}} > 0$. The fourth term in the brackets on the RHS of the above equation becomes

$$\frac{\partial^2 Z_{ij}}{\partial B_{ij}\partial T_{ij}} = -\frac{k-(\sigma-1)}{(\sigma-1)^2}\left(\frac{f_{ij}^X - f_{ij}^L}{T_{ij} - B_{ij}\delta}\right)^{\frac{\sigma-k-1}{\sigma-1}} \frac{(\sigma-1)T_{ij} - [k-(\sigma-1)]B_{ij}\delta}{(T_{ij} - B_{ij}\delta)^2}.$$

Thus, we have $\frac{\partial^2 Z_{ij}}{\partial B_{ij}\partial T_{ij}} > 0$ if $T_{ij} < \frac{[k-(\sigma-1)]B_{ij}\delta}{\sigma-1}$. Furthermore, the sign of $\frac{\partial P_j}{\partial T_{ij}}$ is positive from the proof of Lemma 3. Hence, $\frac{\partial^2 RLF_{ij}}{\partial B_{ij}\partial T_{ij}} > 0$ holds. ∎

Table A.1: Depth and Breadth of RTAs

Depth		**Breadth**	
Field	Policy area	Field	Policy area
(a) Import tariffs	FTA industrial goods FTA agricultural goods	(a) Services	General Agreement on Trade in Services
(b) Non-tariff barriers	Customs administration Export taxes Sanitary and phytosanitary measures Technical barriers to trade Anti-dumping Countervailing measures	(b) Technology	TRIPS IPR Innovation policies Economic policy dialogue Information society Research and technology
(c) Behind the border policies	State trading enterprises State aid Public procurement Anti-corruption Competition policy	(c) Investment/ capital	Trade-related investment measures Investment Movement of capital
(d) Other policies	Consumer protection Data protection Agriculture Approximation of legislation	(d) Labor	Labor market regulation Illegal immigration Social matters Visa and asylum
	Civil protection Education and training Energy Financial assistance Industrial cooperation Mining Nuclear safety Public administration Regional cooperation Small and medium enterprises Statistics Taxation	(e) Non-economic policies	Environmental laws Audio visual Cultural cooperation Health Human rights Illicit drugs Money laundering Political dialogue Terrorism

Source: Limão (2016).

Table A.2: Countries Included in the Analysis

No.	Country	No.	Country
1	Argentina	26	Italy
2	Australia	27	Japan
3	Austria	28	Latvia
4	Belgium	29	Lithuania
5	Brazil	30	Luxembourg
6	Bulgaria	31	Mexico
7	Canada	32	Netherlands
8	Chile	33	New Zealand
9	China	34	Norway
10	Colombia	35	Peru
11	Costa Rica	36	Poland
12	Croatia	37	Portugal
13	Czech Republic	38	Romania
14	Denmark	39	Russia
15	Estonia	40	Slovak Republic
16	Finland	41	Slovenia
17	France	42	South Africa
18	Germany	43	South Korea
19	Greece	44	Spain
20	Hungary	45	Sweden
21	Iceland	46	Switzerland
22	India	47	Turkey
23	Indonesia	48	United Kingdom
24	Ireland	49	United States
25	Israel		

Table A.3: List of RTAs Included in This Study's Dataset

RTA Name	RTA Type	RTA Name	RTA Type
ASEAN Free Trade Area (AFTA)	FTA	EFTA - Colombia	FTA&EIA
		EFTA - Croatia	FTA
ASEAN - Australia - New Zealand	FTA&EIA	EFTA - Israel	FTA
		EFTA - Mexico	FTA&EIA
ASEAN - India	FTA&EIA	EFTA - Peru	FTA
ASEAN - Japan	FTA	EFTA - Turkey	FTA
Australia - Chile	FTA&EIA	EU - Chile	FTA
Australia - New Zealand (ANZCERTA)	FTA&EIA	EU - Croatia	FTA
		EU - Israel	FTA
Canada - Chile	FTA&EIA	EU - Iceland	FTA
Canada - Colombia	FTA&EIA	EU - Mexico	FTA&EIA
Canada - Costa Rica	FTA	EU - Norway	FTA
Canada - Israel	FTA	EU - Switzerland - Liechtenstein	FTA
Canada - Peru	FTA&EIA		
Andean Community (CAN)	CU	EU - Turkey	CU
Central European Free Trade Agreement (CEFTA) 2006	FTA	EU - South Africa	FTA
		Israel - Mexico	FTA
		India - Japan	FTA&EIA
Chile - China	FTA&EIA	Japan - Indonesia	FTA&EIA
Chile - Colombia	FTA&EIA	Japan - Mexico	FTA&EIA
Chile - Costa Rica	FTA&EIA	Japan - Switzerland	FTA&EIA
Chile - Japan	FTA&EIA	Southern Common Market (MERCOSUR)	CU&EIA
Chile - Mexico	FTA&EIA		
China - Costa Rica	FTA&EIA	North American Free Trade Agreement (NAFTA)	FTA&EIA
China - New Zealand	FTA&EIA		
Colombia - Mexico	FTA&EIA		
Costa Rica - Mexico	FTA&EIA	Peru - Chile	FTA&EIA
EC Treaty	CU&EIA	Peru - China	FTA&EIA
EC(12) Enlargement	CU	Peru - US	FTA&EIA
EC(15) Enlargement	CU&EIA	Trans-Pacific Strategic Economic Partnership	FTA&EIA
EC(25) Enlargement	CU&EIA		
EC(27) Enlargement	CU&EIA	Turkey - Chile	FTA
European Economic Area (EEA)	EIA	Turkey - Croatia	FTA
		Turkey - Israel	FTA
European Free Trade Association (EFTA)	FTA&EIA	US - Australia	FTA&EIA
		US - Chile	FTA&EIA
EFTA - Canada	FTA	US - Israel	FTA
EFTA - Chile	FTA&EIA		

Source: WTO website: http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx
Notes: (1) The listed RTAs are all the RTAs notified to the WTO that had come into force by 2012 and that comprised as signatories at least two of the countries included in this study. (2) The acronyms for RTA types stand for free trade agreements (FTA), customs unions (CU), and economic integration agreements (EIA).

Table A.4: Descriptive Statistics

Variable	No. of Obs.	Mean	Std. Dev.	Min.	Max.
RLF (US$ million)	35,831	67.867	488.369	0	16,429.320
RTA *dummy*	35,831	0.345	0.475	0	1
Depth index	32,973	0.303	0.414	0	0.923
$WTO_{TRIPS}^{plus-LE}$ *dummy*	35,831	0.320	0.466	0	1
WTO_{IPR}^{X-LE} *dummy*	35,831	0.240	0.427	0	1
Tech index	32,973	0.180	0.269	0	0.667
RTA_{-IPR} *dummy*	35,831	0.105	0.306	0	1

Table A.5: Correlation of Variables

	RLF	RTA $dummy$	$Depth$ $index$	$WTO^{plus-LE}_{TRIPS}$ $dummy$	WTO^{X-LE}_{IPR} $dummy$	$Tech$ $index$	RTA_{-IPR} $dummy$
RLF	1.0000						
$RTA\ dummy$	-0.0008	1.0000					
$Depth\ index$	0.0017	0.9852	1.0000				
$WTO^{plus-LE}_{TRIPS}\ dummy$	0.0052	0.9456	0.9640	1.0000			
$WTO^{X-LE}_{IPR}\ dummy$	0.0137	0.7770	0.8048	0.8049	1.0000		
$Tech\ index$	0.0051	0.9006	0.9525	0.9267	0.8583	1.0000	
$RTA_{-IPR}\ dummy$	-0.0205	0.4692	0.4003	0.3453	-0.1913	0.1954	1.0000