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November 2019

Innovation and Intellectual Property Policy
Working Paper series no. 16

Available at: https://ideas.repec.org/p/iip/wpaper/16.html

Working Paper Series
STiP lab

Are Foreigners Treated Equally under the Trade-Related Aspects of Intellectual Property Rights Agreement?[1]

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Abstract

The TRIPS Agreement, administered by the World Trade Organisation, ensures the smooth functioning of the international patent system. It promises among others that local and foreign firms are treated in the same, non-discriminatory manner. We test for whether national treatment has been upheld in the five largest patent offices and document the existence of a systematic bias against foreign firms in patent examination decisions. We find that filing international patent applications under the Patent Cooperation Treaty can reduce some of the bias.

JEL Codes: O34, F13, F23, K2, K4

Keywords: discrimination; global patent system; national treatment

[1] Acknowledgements. This work was financed by the Australian Research Council [ARC Linkage Grant LP110100266 "The Efficiency of the Global Patent System"] with partners IP Australia and the Institute of Patent and Trademark Attorneys. We wish to thank Russell Thomson, Terry Healy, Tom Spurling, Rochelle Dreyfuss and Keith Houghton for comments.

1. Introduction

Supra-national treaties, covering ethical and trans-border issues have flourished since World War II. The World Trade Organization (WTO), which evolved from the 1948 General Agreement on Tariffs and Trade, is one of the most prominent examples of supra-national organizations. It seeks to regulate, and enhance, international trade.

The Trade-Related aspects of Intellectual Property rights (TRIPS) Agreement is a legal agreement between all the member nations of the WTO. It was established in 1995 in recognition that, as ideas are global public goods, they demand a global solution. It is backed by the WTO's powerful dispute resolution procedures. A key part of this agreement is Article 3.1, the 'national treatment principle', which states that foreigners should be treated in the same, *non-discriminatory* manner as locals. The national treatment principle was already enshrined in the 1883 Paris Convention for the Protection of Industrial Property. Its intention is to minimise international free-riding on research and development (R&D) activities so that nations pay dues for the use of knowledge created and developed by residents of other countries. The national treatment principle is relevant in many trade-related policy domains, but one obvious area relates to patent examinations, where national patent offices make independent determinations about whether specific local and foreign technologies deserve patent protection.[2]

As important as they are, the impact of trade agreements will be limited if they are not appropriately monitored and enforced. Given TRIPS's influence in shaping the increasingly-

[2] Common to other quasi-judicial decisions, patent granting is a jurisdiction-by-jurisdiction decision—typically a nation. To date, the international patent system operates as a loose federation of national patent offices that make quasi-independent decisions about the patentability of a specific invention based on its novelty, non-obviousness and usefulness.

global innovation value chain, the enforcement of the national treatment principle has particular relevance. Failure to enforce it will weaken R&D investment incentives and inhibit international trade flows (see Scotchmer 2004; Palangkaraya, Jensen and Webster 2017). WTO is a user-led organization that does not enforce their own rules. Users are required to initiate enforcement via either: the Trade Policy Review Mechanism;[3] raising the issue at a TRIPS council meeting; or submitting the issue to the dispute settlement mechanism.

Breaching a non-discrimination obligation necessitates statistical investigation as it is difficult to draw conclusions from single instances of alleged bias.[4] In our case, the most important feature to statistically control for is the quality of the underlying invention. It is hard for a disinterested analyst to claim that a single case of refusal of a foreign application alongside a grant to a local application is discrimination as the foreign application could be of lower quality.

Early work, based primarily on data from the 1980s and 1990s has revealed that patent office behaviour is affected by the residential location of the applicant and inventors. Kotabe (1992) for example, has provided evidence that patent offices from leading industrialised countries seem to discriminate against foreigners with either lower grant rates or longer pendency periods. Liegsalz and Wagner (2013) have found that Chinese applicants achieved faster patent grants at the Chinese patent office than their non-Chinese counterpart. de Rassenfosse

[3] This is a country-specific review conducted by the WTO every three years for the major countries and every five years or more for less developed countries.

[4] Agreements that stipulate forbidden behaviours such as weapons trade or export subsidies, need only hear about single cases of non-compliance to detect a breach. But this method is less convincing where the rules are not absolute, the scope of the evidence is fuzzy and some degree of subjective judgement is required by arbitrators, as in patent law.

and Raiteri (2016) have shown that foreign applicants in China face discrimination in strategic technology areas. Azagra-Caro and Tur (2014) have found a national bias within European Patent Office (EPO) patent examiners' citation behaviour. Finally, Webster, Jensen and Palangkaraya (2014) have found a grant decision bias against foreign applicants at the EPO and the Japanese Patent Office (JPO).

In this paper, we extend the last paper to include more recent data and three more offices, namely the United States Patent and Trademark Office (USPTO), the Korean IP Office (KIPO), and the China National Intellectual Property Administration (CNIPA). Together, the five offices that we consider—collectively known as IP5 offices—account for about 80 per cent of worldwide patenting activity. We also delve deeper into the characteristics of foreign applications that are more likely to be disadvantaged. For example, we investigate whether a unified international procedure for preliminary examination of patentability through the Patent Cooperation Treaty (PCT) helps in reducing the bias.

We estimate a fixed-effect model using application and examination data from the 2000s to test whether there exists a statistical bias in the grant decision against foreign patent applicants. Critically, the fixed-effect estimation method controls for any systematic variation in the 'quality' of the invention and enables us to link the variation in foreignness to the variation in the probability of obtaining a grant. The 'quality' fixed effect captures all factors that are systematic to the invention (such as its non-obviousness or the subject matter) and, therefore, common to all the patent applications within a patent family submitted to the IP5 offices.

Our results confirm the presence of a bias against foreign firms in all five patent offices once we control for invention quality using fixed effects (that is, an average of all offices assessments of the application). Furthermore, we find that foreign applicants that use the PCT route have higher probability of grants in the foreign jurisdictions. However, the use of PCT does not eliminate the disadvantage faced by foreign applicants relative to local applicants.

2. Background

Gaining patent protection is a business imperative for multinational enterprises in patent-intensive technology domains. If patents are 'unjustly' refused, such that getting a patent in multiple jurisdictions for an identical invention is highly uncertain, the global incentive to invest in invention and innovation for that business will be muted (Scotchmer 2004). Investors have shouldered the upfront costs of invention and if they only receive fragmentary patent protection across the world, then they must re-coup returns over a narrower set of (patented) markets than would otherwise have been the case. This might mute the power of the global patent system to stimulate ex ante R&D investment.

Over and above the incentive-dampening effects of free riding, there is increasing concern that discrimination against foreigners in the patent system could act as a 'behind the border' barrier to trade hurting both consumers and firms alike (Wineberg 1988; Lee 2007; Linck and McGarry 1993; Maskus and Penubarti 1995; Smith 1999). Although the exact mechanism through which discrimination occurs is not established, there is some emerging evidence that discriminatory patent refusals do result in lower imports of high-technology goods into that country (Palangkaraya et al. 2017). Behind-the-border barriers can be especially damaging for smaller multinationals for whom breaking into global value chains is the main source of growth.

In a bid to both reduce the cost and unpredictability of the examination decision across national offices, it has become increasingly common for patent offices to share information on applications. The Patent Cooperation Treaty (PCT) is an international patent law treaty introduced in 1970 and administered by the World Intellectual Property Organization (WIPO). It provides a unified procedure for filing patent applications in signatory countries with a common international search report and, if the applicants demand, international preliminary examination on patentability. The common information provided by the international phase of PCT (which is not available for applications filed directly under the traditional 'Paris Convention' route) has the potential for reducing any systematic heterogeneity in the outcomes of patent examination across different jurisdictions.[5]

Nevertheless, despite such measures and the increasing alignment of national patent laws (for example, Lerner 2002), patent offices still make different decisions about the patentability of a specific invention. In our sample of patent applications, we find that only two-thirds of applications that have been submitted to all five IP5 offices in the period from 2000 to 2006 end up with the same outcome. Differences in outcomes between offices might legitimately occur because of different definitions of patentable subject matter (for example, not all offices agree on whether software and business methods should be patented); because of variations in procedural matters or protocols; because offices have higher or lower standards of what determines an 'inventive step' worthy of patent protection; or for a range of other factors.

3. Empirical Strategy

[5] There are other more recent international cooperation initiatives of international patent offices that can potentially make patent examination decision across jurisdictions to be more consistent. For example, the Global Patent Prosecution Highway, established in 2008, further encourages work and information sharing between offices (Carson et al. 2009). In addition, in 2014, the IP5 patent offices also launched the IP5 Patent Prosecution Highway pilot programme under which examination procedures are fast tracked by allowing offices to exploit the works of other IP5 offices. Unfortunately, both initiatives are too recent for us to analyse their impact.

To comply with the national treatment principle, there should be no systematic difference in the examination outcome in any single office between foreign and local applicants, once the 'quality' of the invention is accounted for (namely, all factors that are systematic to the invention such as its non-obviousness or the subject matter). Simple comparisons of grant rates in each office by nationality of the applicant or inventor (for example, Kotabe 1992) do not reveal bias against (or in favour of) foreigners, as it is reasonable to suppose that invention quality can vary by national source.

We test for the presence of a statistical bias related to applicant's country of residence in patent examination decisions by studying differences in examination outcomes for the same invention across multiple offices—thereby explicitly controlling for the quality of the underlying invention. We control for invention quality using fixed effects in panel data regressions on a set of equivalent patent applications (called a patent family) filed across offices. For that purpose, we need to construct a sample of equivalent patent applications.

3.1 Equivalent Patent Applications

Our set of equivalent applications relates to the same underlying invention (i) that has been submitted to multiple international patent offices (h) during 2000 to 2006 (and examined until 2014). As in Webster et al. (2014)'s study, the notion of 'equivalence' is crucial to our analysis. Any analysis of the link between patent grant probability and foreignness needs to ensure that there is no systematic bias arising from any unobserved cross-invention variation such as the quality of invention. We ensure the elimination any cross-invention heterogeneity by employing a within invention analysis, that is the fixed-effect estimation based on the equivalence.

We define equivalent applications as patent applications that protect the same invention in *at least one other* jurisdiction, namely ‘twin’ applications. (Note that since we are compiling data from five patent offices, the dataset will include twins, triplets, quadruplets and quintuplets—thus we have an unbalanced panel.) Equivalent applications are patent applications that claim a one-to-one priority link with a focal priority filing (PF). For example, patent applications US-PF-1 at the USPTO and CN-SF-2 at the CNIPA are equivalent if the US priority filing US-PF-1 is claimed only by the second filing CN-SF-2 in China and if CN-SF-2 claims US-PF-1 as sole priority filing (where SF is second filing).

This definition of equivalent applications excludes applications claiming multiple priority filings and applications claimed as priority filing by multiple patent applications in the same jurisdiction. Thus, in all instances where i) a priority filing is split into several second filings in the same office; and ii) two (or more) priority filings are combined into one second filing, the set of observations is removed from the analysis since it does not pass our definition of equivalence. This restriction ensures that the proxy for invention quality is valid since it is derived from true ‘twin’ applications. Although the decision to drop observations comes at a cost (owing to the possible selection bias introduced), the substantial benefits of having a clean set of patent equivalents examined in multiple patent offices probably outweighs the costs.[6]

3.2 Econometric Model

[6] However, we note that it is hard to say anything meaningful about the extent of this potential selection bias since it is so difficult to compare examination outcomes across offices once you include applications without this one-to-one equivalence.

To control for invention quality and differences in office patentability thresholds, we use a fixed-effect regression model. We employ a reduced-form model of the patent examination decision. Accordingly, we say that the probability (y^*_{ih}) of granting the patent application for invention i by patent office h is a function of whether the applicants are foreign to the patent office (n_{ih}), examining office-indicator reflecting the size of the inventive step demanded by the office (o_h), unobserved quality of the underlying invention (α_i), and other unobserved factors that we assume to be random and independently and identically distributed (ε).[7] Formally, the estimating model is:

$$y^*_{ih} = f(\alpha_i + [n_{ih}, o_h]'\beta) + \varepsilon_{ih} \quad (1)$$

where y_{ih} is the binary observed outcome of the patent examination:

$$y_{ih} = \begin{cases} 1 \text{ if } y^*_{ih} > 0 \text{ (application is granted)} \\ 0 \text{ if } y^*_{ih} \leq 0 \text{ (application is refused)} \end{cases}.$$

In addition to invention quality (α_i), equation (1) also sweeps up a number of attributes of the invention that are common to all applications in its family. These attributes include the technology class, the filing route, the number of offices at which the application was filed, the office of the international search report and whether the application included multi-national inventors or applicants. We will examine whether these attributes moderate or exacerbate the bias against foreign applicants using a series of interaction terms.

We have also data on a number of office-specific family attributes, ($\boldsymbol{z}_{ih}$), that allow us to identify more carefully the features of the application that may contribute towards bias

[7] Note that the office effect (o) captures more than the non-obviousness requirement/inventive step threshold. It captures all unobserved factors that vary systematically across offices.

against foreign applicants. These are PCT status (28.8 per cent of families comprise a mix of PCT and Paris applications); whether the application is in an area of revealed trade advantage for that office; and the volume of filings each applicant has made at each office.

To test the moderating influences of these other factors, we extend equation (1) to:

$$y_{ih}^{*} = f(\alpha_i + [n_{ih}, o_h, \boldsymbol{z}_{ih}]'\beta) + \varepsilon_{ih} \tag{1a}$$

4. Data and Descriptive Statistics

4.1 Data Sources

The dataset is assembled from a variety of data sources. The main data source is the EPO Worldwide Patent Statistical database PATSTAT (de Rassenfosse et al. 2014). The database contains bibliographical and legal status patent data from leading industrialised and developing countries. We extract from PATSTAT information on priority filings and their equivalent(s) and inventor/applicant country of residence. We use the EPO's INPADOC PRS table for PATSTAT to obtain legal status for China and the EPO. We probed the JPO's public access on-line Industrial Property Digital Library Database to recover the legal status for Japan. We crawled the KIPO's public access on-line IPR Information Service to recover the legal status for Korea. The USPTO legal status data was recovered from the Public Pair on-line database. To estimate Revealed Trade Advantage we used UN COMTRADE Database, the International Patent Classification–U.S. SIC Concordance (Silverman 1999), the NBER Concordance of Ten-Digit U.S. Harmonized System Codes and an intermediate concordance between the 6-digit Harmonised Code and SIC.[8]

[8] The data in Silverman (1999) were last accessed on 24/01/2019 and are available at: http://www-2.rotman.utoronto.ca/~silverman/ipcsic/documentation_IPC-SIC_concordance.htm

The complete number of applications to these five offices during 2000–2006 is 1,931,041. If we exclude families with some pending or status missing members and families with only one member, we are left with 1,195,210 applications (510,759 families). From Figure 1, we can see that about 240,000 applications have equivalents in two of the five offices, whereas approximately 24,000 families have equivalents in all offices.

Figure 2 shows that 17 per cent of 'twin' families were refused/withdrawn in both offices, as of 2014 when legal status was recorded, 50 per cent are granted in both offices and 33 per cent have a mixed grant outcome: they are granted in one office and refused/withdrawn in the other. The percentage of families with mixed grant outcome jumps to 59 for 'quintuplet' families.

4.2 Variable Description

The dependent variable is a dummy variable that takes value 1 if the patent application was granted or 0 if it was refused (including quasi-refusals).[9] The key explanatory variable relates to whether the applicants on the patent application have a local address or not. The dummy variable, n_{ih} ($= Foreign\ application_{ih}$), equals one for patent application i at patent office *h* if none of the applicants gave an address within the same jurisdiction as the examining patent office. Note that it is possible for an application to be a foreign applicant at all offices if none of the listed applicants have an address in Europe, the United States, Korea, Japan or China. Similarly, it is possible to be local (namely, non-foreign) at all offices given the

[9] Lazaridis and van Pottelsberghe (2007) have argued that applications to the EPO that were withdrawn after an 'X' or 'Y' citation should be regarded as 'quasi-refusals' as they were probably withdrawn in response to the negative feedback from the examiner.

possibility of multiple applicants. However, as only 1.5% of applications in our dataset include both foreign and local applicants, collinearity rules out including both foreign and local status in the model.

To control for the size of the inventive step demanded by the office, the variable o_h is represented by a series of four office dummy variables, ($USPTO, KIPO, JPO$ and $CNIPA$)—thus, the reference group is the EPO. Finally, the vector of variables, $\boldsymbol{z}_{ih}$, comprises PCT_{ih}, whether the application was filed under the PCT (= 1) or under the Paris Convention (= 0); $Revealed\ Comparative\ Advantage_{ih}$ is the proportion of the share of the value of net exports in each relevant industry (that is, the industry in which patent application i's technology is used) in region h to the share of net exports in the same industry in the world; $Applications\ by\ firm_{ih}$ is the log of the number of applications by applicant i to each office h.

5. Results

Table 1 presents the coefficient estimates obtained from estimating equation (1) using a fixed-effect linear regression model in column (1); a conditional logit regression model in column (2) and the same linear model as (1) but using the same sample as (2) in column (3) . The corresponding simulated marginal effects of being a foreign applicant are presented in Table 2, columns (1), (2) and (3) respectively. The marginal effect estimates reveal that being a local applicant increased the probability of a grant by between 10.5–22.2 percentage points.[10] The higher figure is based on a linear model using the logit estimation sample. It only includes

[10] In terms of the office effects on grant, the JPO has the most stringent test for a grant, followed by the EPO. The CNIPA and the USPTO are similar and the least stringent.

applications with mixed grant-refused outcomes.[11] As such, we can say that the bias against foreign applicants is greater the closer the invention is to the grant threshold.

Extrapolating results from our sample of identical twins to the population of patent applications is not without limitations. However, the rate of anti-foreign bias that we find is likely to represent the lower limit of bias. First, more valuable inventions are more likely to be filed in foreign jurisdictions and hence to end up in our sample (Harhoff et al. 2003). de Rassenfosse and Jaffe (2018) provide evidence that economic value and technical merit are interrelated, suggesting that our sample contains relatively strong patent applications. Second, it is possible that applicants select which foreign offices to apply to—for example, sending the most inventive applications to the toughest patent offices (Europe and Japan) or not sending applications to offices with a perceived anti-foreign bias, further mitigating the estimated bias.[12]

The regression framework allows us to estimate the foreign disadvantage for each patent office. The regression results when foreign application is interacted with the office of application are given in Table 1, columns (4), (5) and (6). The associated simulated marginal effects are presented in Table 2, columns (4), (5) and (6). The results show that the EPO and KIPO have the highest levels of bias against foreign applications.

[11] Indeed, fixed effect (conditional) logit estimation excludes families with identical outcomes in all offices.

[12] However, the data do not seem to support the selection hypothesis that the 'strongest' applications are only sent to the JPO and the EPO. We note that the mean five-year forward citation levels (a proxy for patent importance) for patent applications by US-applicants are: 3.86 for applications sent to the USPTO, 3.73 at the EPO, 4.24 at KIPO, 3.92 at the JPO and 4.13 at CNIPA. These differences across offices are not large and therefore aren't indicative of a serious selection issue.

Two remarks are in order. First, the absolute magnitude of the foreign application bias in an office must be contrasted with the overall grant rate in that office. To illustrate the point, consider the following two cases: (i) a very lax office that grants virtually all patent applications and for which the foreign bias is a mere one percentage point; corresponding for instance to a refusal rate of 1% for locals and 2% for foreigners; and (ii) a stricter office for which the foreign bias is as high as 10 percentage points; corresponding for instance to a refusal rate of 20% for locals and 30% for foreigners. In the former case, foreigners are twice as likely as locals to have their patent application refused whereas in the latter case they are only 50 per cent more likely than locals to be refused a patent. Comparing the magnitude of the office fixed effects with that of the interaction terms, we note that larger biases are found in offices that are also stricter (namely, in offices that have lower fixed effects).

Second, the number of observations differ between the first OLS models and the second and third estimates. This difference is due to the fact that the logit model excludes families with the same examination outcome in all offices as the fixed effect perfectly predicts outcome. Despite the significant change in the composition and size of the estimating sample, we find consistent positive and statistically significant effect of local applicant status. The main difference between models lies in the magnitude of the effect, which is higher for samples consisting of families with mixed outcomes. This is true for all offices but the JPO.

We know the country address of each applicant, and therefore we can investigate whether some national groups experience more than average disadvantage than others. To see this, we estimated the grant (versus refused) decision at each office separately. To control for the quality of the underlying invention, we estimated a 'quality' variable for each family as the mean examination decision at the other offices. At the EPO, Korean applicants suffer from the greatest bias and at the KIPO, Europeans experience the greatest disadvantage. American and Japanese applicants also experience considerable bias at the EPO but this disadvantage is not reciprocated at the USPTO or JPO. At the KIPO, the Japanese experience the least bias, followed by the Chinese. The greatest bias at the USPTO is against Chinese applicants and the greatest bias at the JPO is towards 'Other foreign' nationals. All the biases at the CNIPA are small in absolute terms (partly owing to the fact that the office has a particularly high grant rate).[13]

One might also question whether the foreign bias is in part a reflection of the leniency of the country of origin. If applications from more lenient offices are more likely to be rejected, then the bias could, in part, reflect differences in patenting standards. However, the estimates from Table 3 do not support this hypothesis. For instance, in column (1), the applications arriving at the EPO from American and Japanese applicants (with the USPTO being a lenient office and the JPO being the strictest) are equally disadvantaged relative to local European applicants.

Note that as we have no absolute benchmark of what is a justified or non-justified grant, the bias against foreign applications we discussed above is the mirror image of the bias in favour of local applicants. Thus, it is not clear whether the bias is because foreign applicants are more likely to be incorrectly rejected (Type I error) or whether local applicants are more likely to be incorrectly granted (Type II error). One may argue that a stronger form of bias is whether

[13] This reciprocity, or lack thereof, does not appear to arise from different definitions of patentable subject matter between jurisdictions. An examination of single-offices regression for biotech, software and ICT shows a similar pattern to Table 3. In software (arguably the patentable subject matter area where the EPO and USPTO differ most), it is still Koreans who experience the most bias at the EPO and still the Chinese at the USPTO. Americans do worse at KIPO and the JPO however. The same American pattern is apparent for biotech and ICT.

foreign applicants are more likely than local applicants to be refused an application that should be granted.

To provide a preliminary evidence, we assume that if an application is granted at both of the two most stringent offices (the EPO and JPO), then it should pass the inventive step threshold in the other offices. Accordingly, failure to grant at the other offices can be classified as a Type I error. Conversely, if an application is refused at both the EPO and the JPO, we define such application that has been granted in other offices as Type II error.[14] To see if Type I and II errors are influenced by foreign applicant status, we took the sample of families that had applied to all five offices (186,011 applications). We then counted the number of applications where the family equivalents were both granted at both the EPO and the JPO (30,991) but refused at the USPTO, KIPO and CNIPA (3,633); and both refused at the EPO and the JPO (23,886) but granted at one of the other three offices (8,069). We then estimated:

$$\Pr\,(y^*_{ih} = 0 \mid \text{truegrant} = 1) = f(\alpha_i + [n_{ih}, o_h]'\beta) + \varepsilon_{ih} \quad \forall\, i = USPTO, KIPO, CNIPA \quad (2)$$

$$\Pr\,(y^*_{ih} = 1 \mid \text{truerefuse} = 1) = f(\alpha_i + [n_{ih}, o_h]'\beta) + \varepsilon_{ih} \quad \forall\, i = USPTO, KIPO, CNIPA \quad (3)$$

The estimates presented in Table 4 show that the errors experienced by foreign applications is to their disadvantage—they are more likely to be erroneously refused (by 6.7 percentage points) and less likely to be erroneously granted (by 34.0 percentage points). Or to put it another way, local applicants are more likely to be incorrectly granted an application (under this definition).

[14] An alternative proxy for the Type II error is to use the least stringent office (CNIPA) as the benchmark. If an application is refused by CNIPA, then any grant decision by other office is questionable. The estimate presented in the second column of Table 4 is little different (0.5%) if we define Type II error as being refused in the CNIPA and granted in the other four offices.

As foreshadowed, we also investigated whether the degree of bias against foreign applications is moderated by attributes of the application such as whether the family uses the Paris or the PCT route.[15] Our investigation was complicated by the lack of instrument for the endogenous decision to file under the PCT, even if we are evaluating the decision within the same family. Highly confident applicants can save money and time by applying directly to each national office. In contrast, less confident applicants would file at the local office first and if they received favourable signals proceed to apply in foreign offices under the PCT in order to benefit from the extra time and international research report. In other words, we may expect that the users of PCT are more likely to be relatively more successful in the local office if applicant's confidence is systematically related to success in foreign office. Thus, simply inserting a PCT indicator into equation (1) we may find a negative effect of PCT on foreign bias (that is, exacerbated foreign bias).

We first re-estimated equation (1) using separate samples: applications filed exclusively using the Paris route and applications filed exclusively under the PCT. The results provided in Table 5 columns (1) and (2) show that the foreign bias is stronger for families that use PCT exclusively. However, as argued above, this may simply reflect the sample selection.

We then estimated a slightly different specification by using only the sample of foreign applications and adding a PCT indicator. The results given in Table 5 column (3) show that using the PCT route increases the probability of grant. Because we exclude local applications (hence, we drop the foreign applicant dummy variable), the estimated effect of PCT does not

[15] In our sample, 64.7 per cent of patent families have all applications via the Paris route, 9.0 are all under the PCT, and the remaining 26.3 per cent use a combination of both routes.

suffer from the sample selection problem.[16] However, comparing the marginal effect of using PCT with the size of the foreign applicant bias, we see that the use of PCT may only offset some of the foreign applicant bias.

All PCT applications undergo an early prior art search report (which is performed within 18 months of filing) and applicants can choose any one of 22 accredited national patent offices to act as the International Search Authority (ISA). It does not need to be their local office and we find, for example, that 8.3 per cent of Japanese applicants in our dataset chose the EPO. As a result of this search report, applicants may modify their application and it is possible that the thoroughness of this report assists applicants to craft their application in a way that raises the probability of grant. Table 6 gives a summary of the coefficients on the interaction between foreign application status and specific ISAs. These coefficients are derived from twelve separate regression estimates. The estimates show that both Chinese and European ISAs are associated with an enhanced advantage given to foreign applications. On the other hand, Korea, Spain, the United States and Japan are associated with a lesser advantage for foreign applications.

Finally, we have two other exogenous features of applications that vary within families and therefore allow us to test for proximate factors operating to disadvantage foreign applicants. The effects are represented in Figures 3a, 3b and 4 and are estimated from equation (1a). First, Webster et al. (2014) found that the advantage to local applicants (over foreign applicants) at the EPO and JPO in the 1990s was greater in industries in which the local economy had a high Revealed Trade Advantage. We tested to see if this association still

[16] The identification comes from the variation in PCT_{ih} across foreign offices (h) for any given patent family similar to the identification of treatment effect in a difference-in-differences analysis.

existed and found that it did not. As shown in Figure 3a, it appears that local applications have the greatest advantage in the areas of lowest Revealed Trade Advantage and the bias against foreign applications diminishes for technologies associated with higher levels of Revealed Trade Advantage. However, when we excluded China as shown in Figure 3b, we no longer observe diminishing bias. These results indicate that the relationship between foreign bias and revealed trade advantage is country-dependent, perhaps reflecting the importance to distinguish between high and low value-added exports which cannot be captured by metrics based on gross trade statistics.

Second, we also tested to see if foreign applicants who file large volumes of international applications at each office have an advantage. Our measures of the volume of applications at each office is drawn from our 2000 to 2006 dataset and, as such, we are not able to create an accumulating measure of experience (due to data truncation). However, we believe that our measure, which is the log of the number of applications by each firm at each office, is a reasonable reflection of economies of scale and learning-by-doing within the firm. The results depicted in Figure 4 clearly suggest that experience matters. Large volumes of patent applications filed by each firm at each office increases the probability of grant for both local and foreign applications. However, the effect is greater for foreign applicants with low levels of experience (relative to locals).

In addition, we can test for whether the foreign bias is more acute if there are applicants or inventors from multiple nations (treating Europe as a single nation) and if the application is filed at more offices. Results shown in Appendix Table A reveal that having multi-national applications as either an applicant or inventor increases the advantage to foreign applications. We can employ the same approach to technology class and the results, shown in Appendix

Table B, reveal variation by technology area, with the discrimination being greatest in biotechnology and least for instruments.

Finally, differential treatment of foreign applicants may occur before the application is submitted for examination. Across our five offices, 18.5 per cent of applications are withdrawn before the examination begins. The reasons for withdrawal are various. The applicant may no longer believe the invention has commercial value; the applicant may have had an adverse prior art search report from one or more other offices or the invention may fail a technical milestone. In an extension to the analysis, we have examined whether the behaviour of foreign applicants regarding withdrawals differs from that of local applicants. We have estimated the determinants of withdrawal with a regression model similar to equation (1), but where the dependent variable is a dummy variable that takes value 1 if the patent application was withdrawn or 0 if it proceeded to examination (and regardless of whether it were ultimately granted or refused). We find that foreign applicants are also more likely to withdraw their application before requesting examination compared with local applicants (except at the JPO, where foreign applicants are 0.6 percentage points less likely than locals to withdraw their applications).[17]

6. Discussion

In an earlier study, we revealed a bias against foreign applications filed at the EPO and JPO in the early 1990s (Webster et al. 2014). In the present study, we confirmed the continued existence of this bias using a more recent dataset and a broader cross-section of countries. Coupled with previous work, we find clear evidence of statistical bias against foreigners

[17] The results are available upon request from the authors.

(suggesting that the national treatment principle is not being upheld) and that this bias is not diminishing. This issue should be of serious concern for technology-focused multinational enterprises and the WTO.

In this study, we also examined whether the PCT application route reduces this bias. The PCT was introduced to harmonize and facilitate the international patenting process. We found that the PCT helps improve applicant's chance in getting patents in foreign jurisdictions. Yet, we still found foreign applicant bias when we look only at PCT applications suggesting that the use of PCT does not completely offset the bias.

The WTO is responsible for upholding the TRIPS Agreement via a dedicated council. This council receives notifications in respect to national treatment but to date these appear to refer only to countries seeking exemptions. There appears to be no regular monitoring, despite the evidence and data being available to support such monitoring since the creation of the worldwide PATSTAT database in 2006. Although, all WTO members must also undergo periodic peer review of their trade policies and practices, the verification of national treatment in patent law has been consistently overlooked.

Patents are neither the beginning nor the end of innovation policy. Yet in some markets they matter. There is mounting evidence that shows that the legal right has an effect on commercial outcomes, over and above the technological merits of an invention.[18] If a case can be made for using governmental prerogative to establish and maintain a patent system,

[18] Studies have recently revealed that firms with a granted patent (relative to applications that were refused) have higher: stock market capitalizations, and, for patent-assertion entities, litigation rates (Feng and Jaravel 2019); inventor tenure (Melero et al. 2017); rates of progress to commercialization (Webster and Jensen 2011); and, for startups, employment and sales growth (Farre-Mensa et al. 2017).

then it follows that it should operate in an efficient and non-discriminatory manner. As yet, we do not know the root causes of the observed statistical bias, but it is important to note that we do not believe that any discrimination is explicit—rather it likely relates to some form of implicit discrimination as has been observed in other contexts (for example, Price and Wolfers 2010; Hamermesh and Biddle 1994).

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TABLES

Table 1. Determinants of a patent grant, filing years 2000–2006, equation (1)

Explanatory variables	(1) OLS	(2) Logit[19]	(3) OLS	(4) OLS	(5) Logit	(6) OLS
Application office[a]						
USPTO	0.135**	1.188**	0.364**	0.070**	0.719**	0.184**
	(0.001)	(0.011)	(0.003)	(0.002)	(0.025)	(0.006)
KIPO	0.068**	0.567**	0.181**	0.074**	0.922**	0.220**
	(0.001)	(0.014)	(0.004)	(0.002)	(0.028)	(0.007)
JPO	-0.088**	-0.610**	-0.220**	-0.118**	-1.051**	-0.401**
	(0.001)	(0.011)	(0.003)	(0.002)	(0.020)	(0.005)
CNIPA	0.191**	2.290**	0.545**	0.108**	1.328**	0.341**
	(0.001)	(0.018)	(0.004)	(0.006)	(0.081)	(0.017)
Residence of applicants[b]						
Foreign application	-0.105**	-0.815**	-0.222**			
	(0.001)	(0.008)	-0.222**			
Foreign application * EPO				-0.155**	-1.207**	-0.403**
				(0.002)	(0.021)	(0.006)
Foreign application * USPTO				-0.056**	-0.550**	-0.136**
				(0.002)	(0.021)	(0.005)
Foreign application * KIPO				-0.158**	-1.667**	-0.451**
				(0.002)	(0.026)	(0.006)
Foreign application * JPO				-0.100**	-0.458**	-0.104**
				(0.002)	(0.016)	(0.004)
Foreign application * CNIPA				-0.048**	-0.067	-0.131**
				(0.006)	(0.081)	(0.017)
Estimation method	Fixed effects (invention quality)	Fixed effects (invention quality)	Fixed effects (invention quality)	Fixed effects (invention quality)	Fixed effects (invention quality)	Fixed effects (invention quality)
Observations	1,110,786	358,255	358,255	1,110,786	358,255	358,255
R-squared	0.106		0.281	0.108		0.291
Number of patent families	426,335	132,463	132,463	426,335	132,463	132,463
Rho	0.361		0.0811	0.360		0.0868

Note: [a] The reference office is always the EPO. Only includes patent families with at least two known grant or refuse decisions, and a known decision for all members. [b] Foreign application is an application where no applicants have a local address. The OLS model includes a constant. Standard errors in parentheses ** p<0.001.

[19] To avoid inconsistency in our parameter estimates due to the incidental parameter problem arising from the small 'time' dimension of our panel data (up to five patent offices), we estimated all fixed effect logit models as conditional logit models using conditional maximum likelihood (Greene 2002, p. 695–700).

Table 2. Simulated marginal effects of being all foreign applicants versus at least one local applicant

	(1) OLS	(2) Logit	(3) OLS	(4) OLS	(5) Logit	(6) OLS
No interaction	-0.105	-0.168	-0.222			
EPO				-0.155	-0.243	-0.403
USPTO				-0.056	-0.111	-0.136
KIPO				-0.158	-0.335	-0.451
JPO				-0.100	-0.092	-0.104
CNIPA				-0.048	-0.013	-0.131

Note: Column numbers correspond to column numbers in Table 1.

Table 3. Determinants of a patent grant, filing years 2000–2006, single office estimations

Explanatory variable	(1) EPO	(2) USPTO	(3) KIPO	(4) JPO	(5) CNIPA
Quality	0.247**	0.007**	0.244**	0.273**	0.070**
	(0.003)	(0.001)	(0.003)	(0.003)	(0.002)
Any applicants[b] who are...					
European		-0.045**	-0.189**	-0.113**	0.010**
		(0.001)	(0.003)	(0.002)	(0.002)
American	-0.163**		-0.157**	-0.143**	0.004
	(0.002)		(0.003)	(0.002)	(0.002)
Korean	-0.269**	-0.036**		-0.162**	-0.019**
	(0.005)	(0.002)		(0.003)	(0.002)
Japanese	-0.153**	-0.000	-0.082**		0.010**
	(0.002)	(0.001)	(0.002)		(0.002)
Chinese	-0.126**	-0.097**	-0.127**	-0.134**	
	(0.010)	(0.004)	(0.012)	(0.011)	
Other foreign	-0.083**	-0.010**	-0.167**	-0.178**	0.006
	(0.006)	(0.003)	(0.009)	(0.007)	(0.003)
Observations	171,021	344,718	129,527	288,626	176,894
R-squared	0.073	0.006	0.084	0.052	0.014

Note: [a] Only includes patent families with at least two known grant or refuse decisions, and a known decision for all members. [b] Applicants are deemed a nationality based on the address given on their application. Standard errors in parentheses ** p<0.001.

Table 4. Determinants of Type I and II errors, applications to five offices, filing years 2000–2006, equation (1)

Explanatory variables	(1) Refused but a true grant (Type I error)	(2) Granted but a true refuse (Type II error)
Application office[a]		
USPTO	0.015**	0.074**
	(0.004)	(0.006)
CNIPA	-0.089**	0.035**
	(0.004)	(0.006)
Residence of applicants[b]		
Foreign application	0.067**	-0.340**
	(0.007)	(0.008)
Estimation method	FE OLS	FE OLS
Observations	30,991	23,886
R-squared	0.031	0.124
Number of patent families	10,893	7,985
Rho	0.341	0.395

Note: [a] The reference office is the KIPO. Only includes patent families with five known grant or refuse decisions, and a known decision for all members. [b] Foreign application is an application where no applicants have a local address. The OLS model includes a constant. Standard errors in parentheses ** p<0.001.

Table 5. Determinants of a patent grant, PCT status, filing years 2000–2006, equations (1) and (1a)

Explanatory variables	(1) All Paris	(2) All PCT	(3) All foreign
Application office[a]			
USPTO	0.204**	0.050**	0.136**
	(0.001)	(0.004)	(0.002)
KIPO	0.140**	0.149**	0.061**
	(0.002)	(0.012)	(0.002)
JPO	-0.041**	-0.107**	-0.076**
	(0.002)	(0.004)	(0.002)
CNIPA	0.230**	0.179**	0.197**
	(0.002)	(0.005)	(0.002)
Residence of applicants[b]			
Foreign application	-0.084**	-0.169**	
	(0.001)	(0.004)	
PCT			0.033**
			(0.002)
Estimation method	FE OLS	FE OLS	FE OLS
Observations	683,720	92,570	742,308
R-squared	0.120	0.136	0.102
Number of patent families	271,375	38,088	425,530
Rho	0.364	0.338	0.470

Note: [a] The reference office is always the EPO. Only includes patent families with at least two known grant or refuse decisions, and a known decision for all members. [b] Foreign application is an application where no applicants have a local address. The OLS model includes a constant. Standard errors in parentheses ** p<0.001.

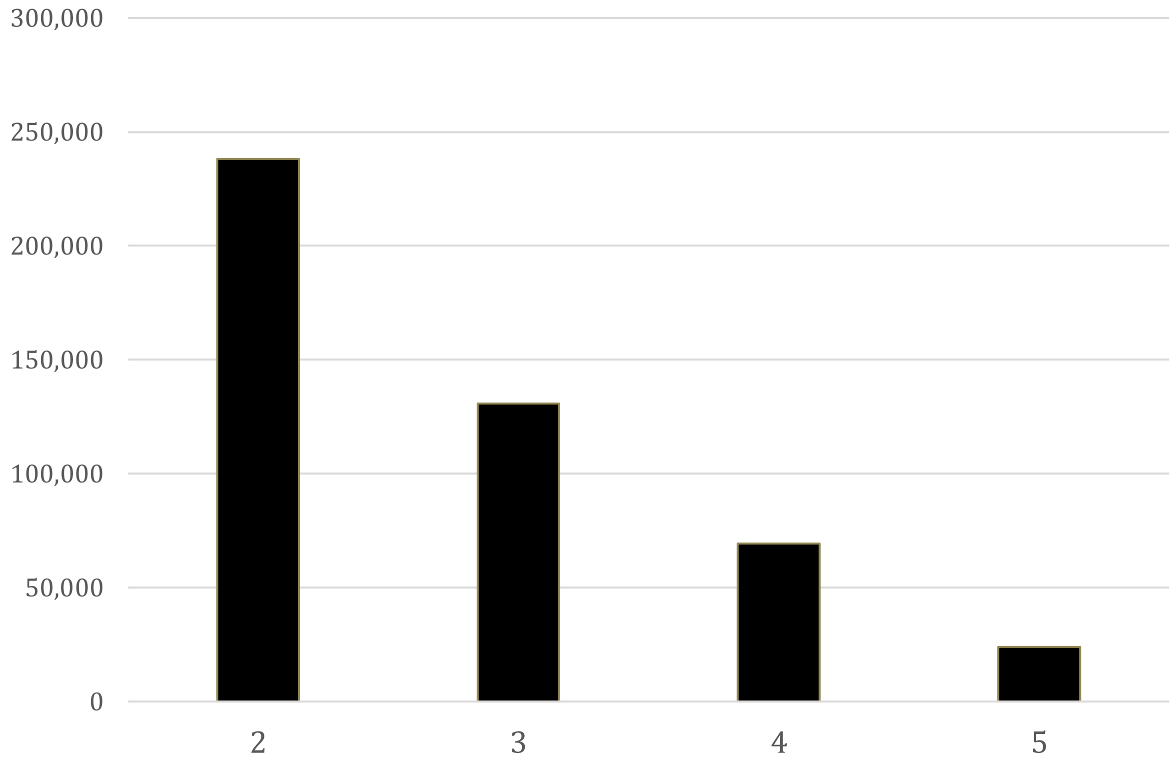
Table 6. Regression coefficients of the effect of being a foreign applicant interacted with specific International Search Authority (ISA), PCT applications only, filing years 2000–2006

ISA	Coeff (se)	Number of applications to ISA		ISA	Coeff (se)	Number of applications to ISA	
		Foreign	Local			Foreign	Local
Austria	0.049 (0.020)	355	93	Finland	0.119 (0.152)	6	2
Australia	0.139 (0.080)	23	144	Japan	-0.134** (0.005)	11,738	1,208
Canada	0.046 (0.101)	15	188	Korea	-0.069** (0.009)	2,202	199
China	0.105** (0.012)	1,080	104	Russia	0.165 (0.116)	11	157
Europe	0.132** (0.003)	41,686	8,085	Sweden	-0.013 (0.009)	2,108	799
Spain	-0.064** (0.021)	347	48	USA	-0.121** (0.005)	8,462	1,029
				TOTAL		*68,033*	*12,056*

Note: Only includes PCT patent families with at least two known grant or refuse decisions, and a known decision for all members. The OLS includes a constant. Standard errors in parentheses ** p<0.001.
Source: Twelve separate estimations based on Equation 1 with the inclusion of a Local Applicant dummy variable interacted with specific characteristic.

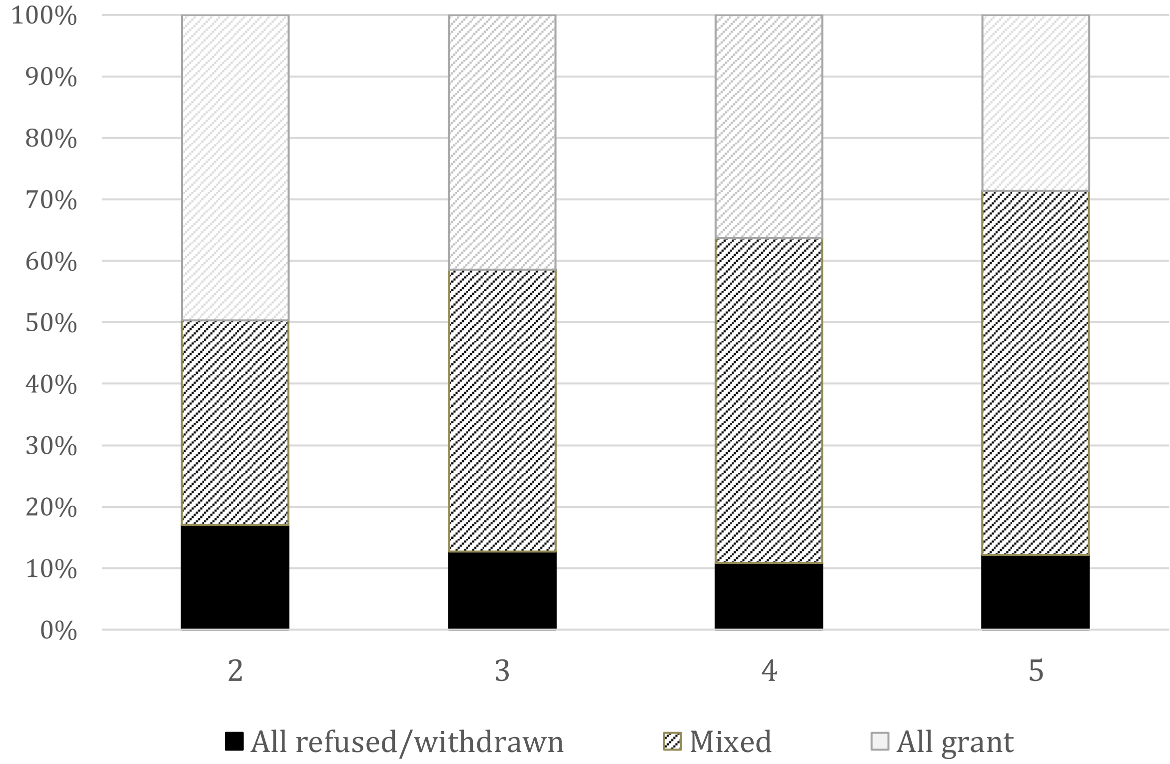
FIGURES

Figure 1. Number of patent families by size, filing years 2000–2006



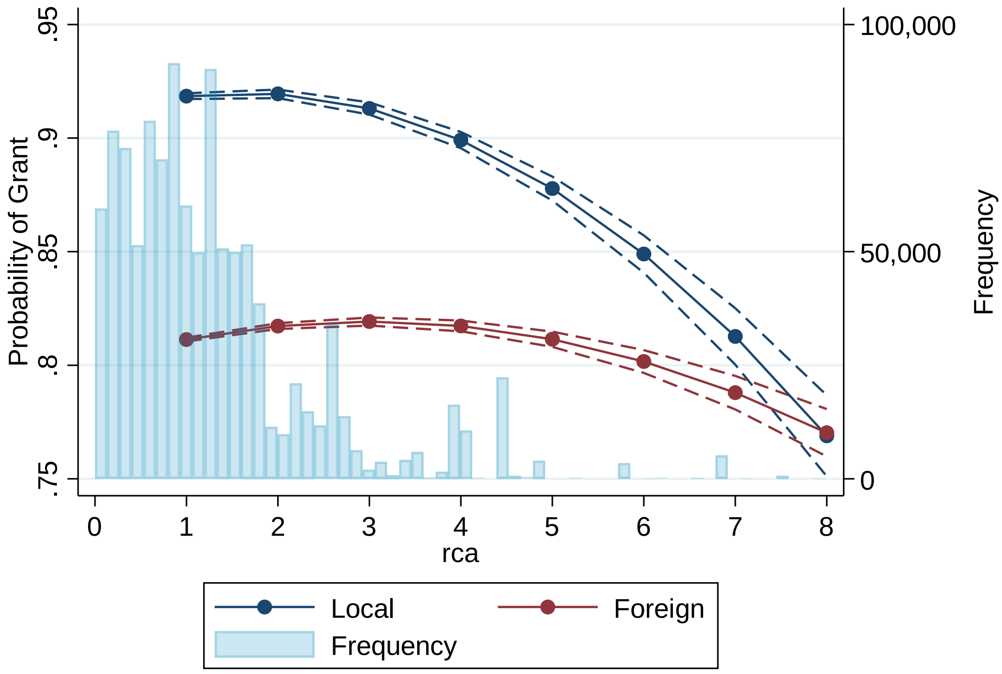
Note: We define equivalent applications as patent applications that protect the same invention in *at least one other* different jurisdiction where each secondary filing claims a one-to-one priority link with a focal priority filing. Excludes families with only one application. Includes all applications regardless of outcome (grant, refused, withdrawn or pending). See main text for additional details.

Figure 2. Percentage distribution of application outcome by family size, filing years 2000–2006



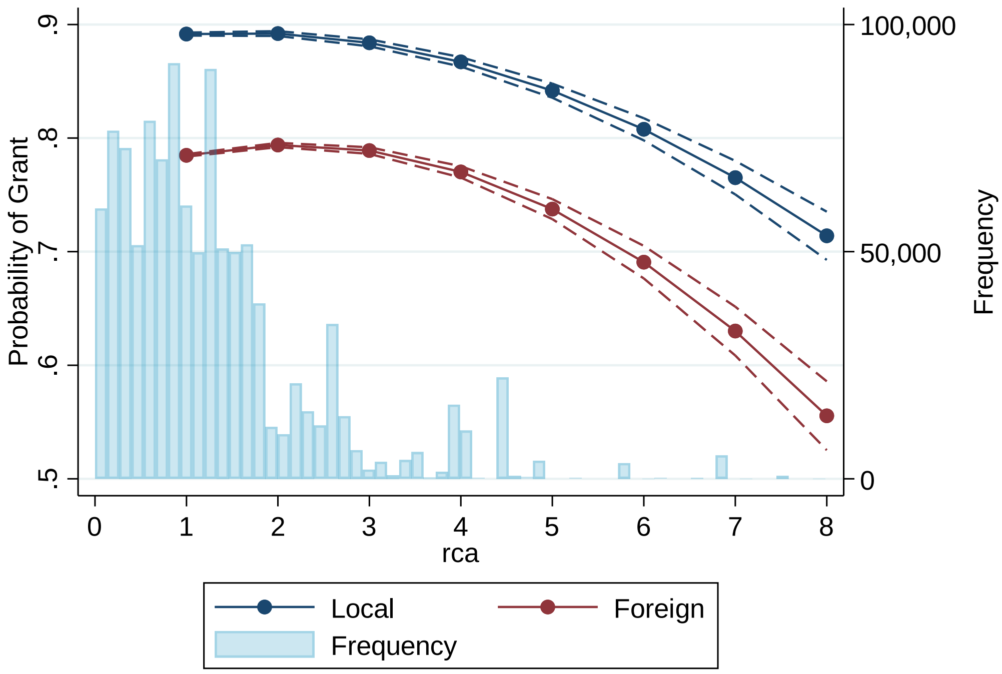
Note: A family size of 'x' means that patent protection for an invention has been applied for in 'x' of the IP5 offices.

Figure 3a. Effect of Revealed Trade Advantage on the probability of grant, Local and Foreign applicant status, 2000–2006, All IP5 countries.



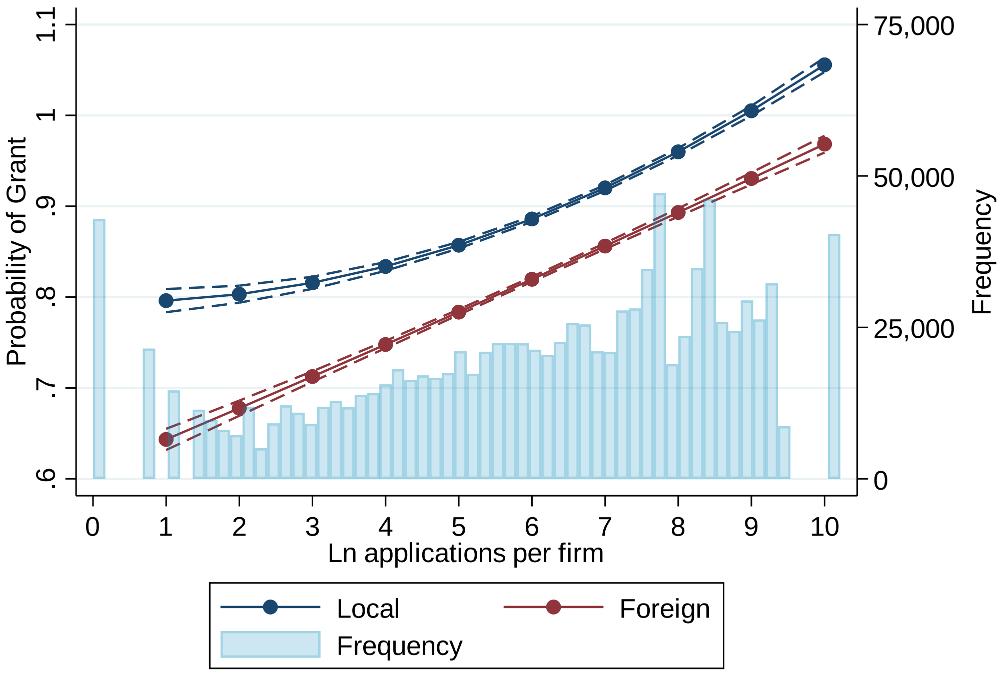
Note: Frequency is the frequency of applications.

Figure 3b. Effect of Revealed Trade Advantage on the probability of grant, Local and Foreign applicant status, 2000–2006, excluding China.



Note: Frequency is the frequency of applications.

Figure 4. Effect of applicant firm experience on the probability of grant, Local and Foreign applicant status, 2000–2006.



Note: Frequency is the frequency of applications.

Appendix Table A. Determinants of a patent grant, foreign application status interacted with application characteristics, filing years 2000–2006

Explanatory variables	(1) OLS	(2) OLS	(3) OLS
Application office(omitted)			
Residence of applicants[b]			
Foreign application	-0.105**	-0.105**	-0.042**
Interacted with…	(0.001)	(0.001)	(0.002)
Multi-national applicants	0.070**		
	(0.007)		
Multi-national inventors		0.022**	
		(0.004)	
Number of offices			-0.020**
			(0.001)
Observations	1,110,786	1,110,786	1,110,786
R-squared	0.106	0.106	0.107
Number of id	426,335	426,335	426,335
Rho	0.361	0.361	0.360

Note: [a] The reference office is always the EPO. Only includes patent families with at least two known grant or refuse decisions, and a known decision for all members. [b] Foreign application is an application where no applicants have a local address. The OLS model includes a constant. Standard errors in parentheses ** p<0.001.

Appendix Table B. Determinants of a patent grant, foreign application status interacted with major technology class, filing years 2000–2006

Explanatory variables	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS
Application office (not reported)									
Residence of applicants[b]									
Foreign application	-0.104**	-0.106**	-0.105**	-0.107**	-0.108**	-0.102**	-0.103**	-0.104**	-0.103**
Interacted with…	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Biotechnology	-0.089**								
	(0.008)								
ICT		0.006**							
		(0.002)							
Software			0.007						
			(0.003)						
Electrical				0.013**					
				(0.002)					
Instruments					0.023**				
					(0.002)				
Chemical/pharma						-0.038**			
						(0.003)			
Process engineer							-0.014**		
							(0.002)		
Mech engineer								-0.005	
								(0.002)	
Other									-0.036**
									(0.003)
Observations	1,110,754	1,110,754	1,110,754	1,110,754	1,110,754	1,110,754	1,110,754	1,110,754	1,110,754
R-squared	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106
Number of id	426,322	426,322	426,322	426,322	426,322	426,322	426,322	426,322	426,322
Rho	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361

Note: [a] The reference office is always the EPO. Only includes patent families with at least two known grant or refuse decisions, and a known decision for all members. [b] Foreign application is an application where no applicants have a local address. The OLS model includes a constant. Standard errors in parentheses ** p<0.001.