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ABSTRACT

While most developed countries apply the same criteria to determine whether an invention is eligible to be protected by a patent, there are substantial procedural differences in the way in which different patent offices examine a patent application. This means that a patent application may be granted in one jurisdiction but rejected in others, which raises welfare concerns about the ability of patents to provide an *ex ante* incentive for investment. In this article, we analyze whether there are systematic differences in patent application outcomes across the trilateral patent offices. In order to determine how much "disharmony" exists, we examine whether the patent offices make consistent decisions *for a given invention* using a dataset of 70,000 patent applications that have been granted in the US and submitted in Japan and Europe and have a single, common priority application. Specifically, we model the patent application outcomes using a multinomial logit to see how the decisions made by the patent offices vary across different patent characteristics such as technology area, non-obviousness of the invention and priority country.

1. INTRODUCTION

There has recently been much debate about the merits of harmonizing international patent laws (see Duffy 2002; Barton 2004; Mossinghoff and Kuo 1998 for example). Bilateral and multilateral trade agreements and treaties – such as TRIPS and the US-Australia Free Trade Agreement – which promote consensus on issues such as copyright term extension and patent coverage, have flourished. Moreover, it is a condition of TRIPS that all signatories to the agreement apply the same criteria – novelty, non-obviousness and utility – to determine whether an invention is eligible to be protected by a patent. Despite this, there are substantial procedural differences in the way in which different patent offices search for prior art and interpret non-obviousness. The Trilateral Patent Offices – the United States Patent Office (the USPTO), the Japanese Patent Office (the JPO) and the European Patent Office (the EPO) – have recognised the importance of consensus in patent examination procedures and have considered ways in which these differences can be attenuated.

In this article, we analyze one aspect of the patent harmonization debate: whether there are systematic differences in patent application outcomes – which we define as withdrawn, pending, rejected or granted – across the trilateral patent offices. Recent evidence suggests that despite the fact that all three offices have been working towards a consistent interpretation of patentability thresholds, such “disharmony” in patent application outcomes may exist. For example, Quillen and Webster (2001) compared the aggregate grant rates in the USPTO, the EPO, the JPO and Germany and found that the proportion of patent applications which are approved as patents varies between 47 per cent (Germany) and 97 per cent (USPTO). However, this comparison is based on aggregate statistics from each of the offices and therefore it is not possible to determine whether the difference in observed granting rates is caused by the quality of the patent application or differences in the outcome of the examination process. In order to determine how much disharmony exists, what we are interested in is whether the patent offices make consistent decisions *for a given invention*.

To account for the effects of different patent applications, we have limited our analysis to patent applications that have been submitted to all three trilateral offices and have a single common priority application (and should therefore cover the same invention specifications).[1] We constructed a dataset consisting of the population of 70,000 non-PCT[2] single, common priority patent applications (unit records) with priority years inclusive of the period 1990 and 1995. Data on *applications* from the US is not available for this period, and therefore our dataset consists of all US *granted* patents which were also the subject of patent applications in the EPO and the JPO. We analyse the pattern of patent application outcomes in each patent office over time and across a number of variables. The results suggest that much "disharmony" exists: of those patents granted by the USPTO, for example, 14.6 per cent were rejected by the JPO and 3.8 per cent were rejected by the EPO. We then model the patent application outcomes at both the JPO and the EPO using a multinomial logit to analyse how the decisions made by the patent offices vary across different patent characteristics such as technology area, non-obviousness of the invention and priority country.

The paper is structured as follows. In the following section, we consider some background to the patent harmonization debate, compare the existing differences in patent law (and patent examination processes) across different jurisdictions and consider what factors might affect the decision to grant a patent in one jurisdiction but not another. In section 3, we provide information on the construction of the patent dataset and in section 4, we provide some descriptive analysis on the characteristics of the patents in the dataset. In section 5, we model patent application outcomes at the EPO and the JPO using a multinomial logit model. Finally, some conclusions and implications for the patent harmonization debate are drawn.

2. BACKGROUND

Although it is a simplification of affairs, the current state of play with regard to international patenting is that that an inventor who wants legal protection in different countries must apply for a patent in each jurisdiction. Once a patent application has been lodged at the relevant patent

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[1] Given that there is considerable interaction between the applicant and the office during the course of the examination process, it is possible that patents with common single priority date do not have identical claims (and therefore the scope of the patent is different). However, we cannot compare the detail of the claims in each patent office as it is not directly observable from the data sources we use.

[2] Non-PCT applications were chosen because of the ease in downloading unit records. A comparable dataset using PCT applications, which requires the Japanese applications to be translated into English, will be constructed in the future. We discuss possible selection biases that might arise from our use of non-PCT applications later in the paper.

offices, each office then undertakes its own examination of the application. Although the same patentability threshold applies, each office conducts its own search for prior art and uses different tests to examine the size of the inventive step involved in the invention. Thus, it is possible that a single invention that results in patent applications in multiple jurisdictions will be granted by one patent office and rejected by others.

There are several apparent problems with the existing state of affairs; problems which are at the centre of the push for harmonizing international patent procedures.[3] First, the fact that an invention could be granted protection in one market but denied protection in others creates uncertainty for multinational firms interested in launching new products in multiple markets. From a welfare perspective, either it attenuates the *ex ante* incentive to invest in innovation by permitting copying in one jurisdiction or it implies an unwarranted grant of a monopoly patent right in the other jurisdiction. Secondly, the existence of independent patent examinations in each patent office is inefficient: the duplication of examination costs has been conservatively estimated to be in the order of US$150 million for filing a patent in two jurisdictions (Barton 2004). The estimate is conservative as it does not include translation costs (which are substantial, for example, when applying for a Japanese patent in English) or additional legal fees associated with patent application; it merely accounts for the additional filing fees incurred when applying for a patent in two jurisdictions.

While there are strong *a priori* reasons for arguing that patent harmonization (at least of the examination process) will eliminate the inefficiencies and uncertainty created by the existing system, the case for harmonization is tempered by the fact that it is unclear which country's patenting standard should be adopted. If the lowest common denominator became the universal standard, there may be adverse consequences for future innovation investment since a low inventive step threshold may induce patent thickets and other anticompetitive effects (Jensen and Webster 2004; Shapiro 2001; Merges 1999; Farrell and Merges 2004). In addition, a world patent system would prevent sovereign nations from making unilateral changes to national legislation in the event of unforeseen future events. Finally, a world patent may impose deadweight losses on

[3] There are four dimensions of patent harmonization: legislation, application, examination and enforcement. However, we are only concerned here with the application and examination procedures. Thus, we ignore issues such as differences in the legal rules relating to the enforcement of patents in court.

developing countries who are signatories to the PCT or Paris Convention, but may not directly benefit from enforcing a large number of developed country patents.

This paper, however, is not about the welfare effects of patent harmonization. Rather, it is concerned with a set of simpler issues: how much disharmony in patent application outcomes currently exists across the major patent offices in the world? Does the observed disharmony vary across variables such as the area of technology and the priority country?[4] In order to address these questions, we need to consider what factors may affect the outcome of the patent application procedures in the different patent offices.

While there is little formal theory to guide us on this issue, there are a number of possible reasons why patent application outcomes for a given invention may vary across patent offices. First, there may be differences in the legislative environment governing the different offices. The (few) clearly recognised differences between legislation in the trilateral jurisdictions include the 'first-to-invent' versus the 'first-to-apply' rule, the scope of patentable matter and the interpretation of utility in biotechnology. Such differences in interpretation over what is patentable are known to have a difference in the outcomes of the patent examination process.[5] Furthermore, there are also differences in patent examination procedures. For example, prior to 2001, the JPO allowed up to seven years from filing in Japan before the application was either examined or withdrawn, while the EPO requires examination within 6 months from the production of the prior art search report.[6] Thus, a patent which is granted by the EPO may end up being withdrawn (or abandoned) at the JPO if, by the end of the 7-year period, the invention appears to have no commercial potential.

[4] In a separate paper, Palangkaraya, Jensen and Webster (2005), we examine the more complex issue of the determinants of the observed differences in patent examination decisions at the EPO and the JPO.

[5] See Howlett and Christie (2003), who examine the different examination outcomes across the trilateral patent offices for a number of hypothetical biotech patent applications. They find significant differences across the three offices and are able to provide insight into the causes of the differences because they are able to observe the grounds for rejecting the patent application (non-obviousness, lack of utility, etc.). We, however, only observe the aggregate decision (reject, grant) and not the reasons for a particular decision.

[6] In our dataset, the average file-to-grant time of 2.0, 4.5 and 6.7 years was recorded for the USPTO, EPO and JPO respectively. Only application year was available for the USPTO and we assumed that each application was filed on 1 July in each year. Twenty-four per cent of EPO applications were by 2004 either withdrawn or pending. The respective figure for the JPO was 40 per cent.

Secondly, institutional factors may also affect the patent application outcomes since differences in resource allocation decisions across the offices may affect the quality of the examination (as measured either by the time spent on each application or by the calibre of the examiner). According to Cockburn et *al.* (2002), examiners in more specialised areas have greater latitude as there are fewer peers to provide checks and balances than other areas. Moreover, the incentives provided to patent examiners may affect patent application outcomes. In the USPTO, for instance, patent examiners' pay depends on the number of applications disposed of which may provide a perverse incentive for patent examiners in the USPTO to grant "bad" patents since the USPTO also has a policy of granting continuations which makes it difficult for patent examiners to reject patents (Lemley and Moore 2004). Offices also differ in the way in which they determine whether an invention embodies an inventive step. The EPO for example uses a 'problem-solution approach' whereas the JPO assess what a person skilled in the art would do after searching the prior art (Howlett and Christie 2003).

Thirdly, applicant behaviour may affect the outcome of the patent application process since the decision taken in each office does not occur within a vacuum: interaction between the applicant – or their agent – and the examiner, is likely to affect the final outcome in each office. Such behaviour is motivated by the costs of the interaction and the commercial benefits from selling into each national market. For example, a grant decision may be more likely if applicants are more persistent and amenable to revising their application than is otherwise the case.

Finally, the characteristics of the patents may affect the patent application outcomes. We have identified four such characteristics: the area of technology, the increment in originality over existing prior art, the complexity of the patent application and the priority country. Given that these characteristics are directly observable, we focus here on how patent application outcomes vary across these dimensions. Considering the effects of the field of technology, we argue that divergent patent examination outcomes for the same application may be more likely in certain technology areas. For example, if the application is in a technology field that is an emerging field, or when the application of the patent law to the field is relatively new, it may be much harder to determine whether the application meets the patentability criteria. Moreover, the interpretation of the patentability criteria may differ from office to office. Biotechnology and IT may be examples where such difficulties arise. We also expect that it is harder to reach consistent and harmonious outcomes in technologies that are less codifiable or more uncertain.

Another patent characteristic that should have an impact on patent application outcomes is the size of the inventive step since it should be easier to decisively and consistently accept patent applications which are appreciably more inventive than existing art than is otherwise the case. The difficulty with testing this hypothesis lies in the fact that we cannot observe the size of inventive step of a given patent application. Instead, we proxy the size of the inventive step with the number of forward citations, although there is also some empirical evidence to suggest that other variables such as whether the patent was subjected to opposition proceedings at the EPO could also be a good proxy for inventive step.[7] Similar to academic citations, we postulate that people – applicants, patent attorneys and examiners – find it easier to cite the 'stand out' publications from the past, and these tend to represent papers with the greatest set of new ideas for the time.

The last patent characteristic that may affect the patent application outcome is the country of origin of the patent application. There are numerous reasons why patent application outcome may vary with priority country status: local applicants may be more familiar with the idiosyncrasies of the local patent system, for example, or it is possible that difficulties in translation – relating to both language and cultural context – will disadvantage foreign applications relative to domestic applications. While others have argued that the fact that foreign applications have a lower probability of a positive decision may be due to the inclination by patent offices to use patents as a non-tariff trade barrier (see Linck and McGarry 1993) or for xenophobic reasons,[8] we cannot untangle these effects from the possibility that the observed lower probability is simply a result of errors in translation or other non-strategic reasons. All we intend to do here is to analyse how the

[7] The EPO has a formal opposition process which encourages challenges from third parties before a final decision is made. In 1997, 6.3 per cent of interim patent grants were opposed. Oppositions begin immediately from the interim grant and must be filed within 9 months. Once filed, the opposition process takes on average about 3 years to complete (Graham et *al*. 2002). The opposition decision is determined by a three-person committee and about a third result in a revocation. According to Graham et *al*. (2002), revocation is more likely in new technology areas and also, but perhaps related to this, in applications where there are fewer claims.

[8] Moore (2003), for example, provides some evidence that there is bias against foreigners in American courts with regard patent litigation cases and it is also possible that similar biases exist at the patent examination stage.

patent examination outcome varies by the country of priority without attributing any possible causal reasons as to why this may occur.

3. DATA

In order to analyse differences in patent application outcomes, we constructed a dataset consisting of the population of 70,473 non-PCT[9] single, common priority patent applications (unit records) with priority years inclusive of the period 1990 and 1995. The dataset was compiled from four main sources:

(1) the OECD Triadic Patent Family (TPF) Database,[10]
(2) the EPO's public access online database (*esp@cenet*[11]),
(3) the JPO's public access online Industrial Property Digital Library (IPDL) databases (Patent & Utility Model Concordance, both English[12] and Japanese[13] versions, and the Japanese only database[14]), and
(4) the NBER Patent-Citations Data File (Hall et *al*., 2002).

The first database provides us with a list of triadic patent families defined as "a set of patents taken in various countries to protect a same invention" and which "priority application must have at least one equivalent patent at the EPO, at the USPTO, and at the JPO" (Dernis and Khan 2004, p.11). The TPF database contains triadic patent families for patents with priority years in the period of 1978-2003. However, in order to allow for ample examination time and minimise the amount of data truncation with regards to the application outcome, we only used data with priority years up to 1995. In effect, this provides approximately eight years of examination time from the claimed priority application since we did not extract the data from the online EPO and JPO databases until late 2004. In addition, in order to take into account changes in patent application procedures at the JPO following the 1988 Japanese Patent Law reforms,[15] we limit

[9] Non-PCT applications were chosen for ease of collection. The PCT data set has not yet been constructed.
[10] http://www.oecd.org/LongAbstract/0,2546,en_2649_33703_30921914_1_1_1_1,00.html
[11] http://ep.espacenet.com/search97cgi/s97_cgi.exe?Action=FormGen&Template=ep/EN/home.hts
[12] http://www4.ipdl.ncipi.go.jp/Tokujitu/tjbansakuen.ipdl?N0000=116
[13] http://www.ipdl.ncipi.go.jp/Tokujitu/tjbansaku.ipdl?N0000=110
[14] http://www1.ipdl.ncipi.go.jp/SA1/sa_search.cgi?TYPE=000&sTime=1089941778920
[15] See, for example, Sakakibara and Branstetter (2001).

our data to those patent applications whose priority year is 1990 or later. Considering the entire dataset, 99.86 per cent of priority applications were lodged in both the JPO and EPO by the end of 1996. Finally, to control for the quality of application, we only used patent families with a single priority application. Patent families with multiple priorities may have multiple applications (through divisionals), which would result in a variation in the applications filed across offices making comparing the outcomes problematic.[16] Finally, it was not possible to extract information on PCT examination outcomes in the JPO and we were forced to limit our analysis to non-PCT filings only.[17] Thus, all 70,473 patents in our final dataset relate to non-PCT complete patent application with a single patent application filed at the EPO, a single patent application filed at the JPO, and a single patent application which has been granted as a patent by the USPTO. A summary of the numbers of complete patent applications is provided in Table 1.

Table 1: Summary of Complete Patent Applications in the Trilateral Offices, 1990-1995

Office of Application	Complete Patent Applications/Families
All USPTO applications	843,435
All EPO applications	433,186
All JPO application	2,191,084
All Triadic Patent Families	190,583
• PCT families	18,488
• Non-PCT families	172,095
-single priority	70,477
-multiple priorities	101,618

While the aim of selecting only single-priority, single-application filings was to ensure we had a matched sample with respect to both the invention and the substance of the application as far as possible, the effect of this selection, together with the necessity to limit ourselves to non-PCT filings, suggests that our dataset may be a biased sample of the population of all applications filed at the USPTO, the EPO and the JPO. In particular, it is possible that the applications in our dataset have more commercial potential than applications that were confined to only one national office, but possibly less commercial potential than applications filed in more than three offices (and would thus probably result in taking the PCT route). The effect of disregarding applications

[16] With a similar reason, we also drop any families involving continuation, continuation-in-parts, or divisional patent applications at the USPTO.
[17] However, PCT applications only represent 10 per cent of triadic patent families during this period.

with multiple priorities may also introduce (unknown) biases.[18] However, we have no *a priori* reason why these selection biases will affect the size of our tested variables on the application outcomes, and accordingly we accept, for the time being, our estimated coefficients as being unbiased and representative.

The second and third data sources provide us with information on the status of applications at the EPO and the JPO. Using the list of EPO and JPO application numbers in the TPF database, we downloaded all necessary information from these online databases corresponding to each patent application. The types of information we collected include dates of filing, publication, examination request, notification of refusal, withdrawal, abandonment, rejection, appeal, appeal decision, grant/registration, and opposition, as well as, from the EPO database, certain characteristics of the patent applications such as technology classes, names and countries of inventors, names and countries of applicants, title, citations and claims. Based on the dates collected above, we classified the outcome of the patent examination process as pending, withdrawn, rejected or granted.[19] Finally, we match-merged the applications data we obtained from the TPF database with the NBER patent database using the USPTO patent numbers. This provides us with USPTO patent information which is not available in the TPF database such as the number and country of inventors, technology field, and number of citations made and received.

4. DESCRIPTIVE ANALYSIS

4.1 Gross differences in patent application outcomes

Table 2 and Table 3 show the application outcomes for the set of matched patent applications in the JPO and EPO respectively. Since we cannot access unit record data on applications of the USPTO, all data are conditional on the application being granted in the US. There are a number

[18] In addition, we excluded applications that resulted in divisionals or continuations, but these only affected 4 out of our population of 70,477 families.

[19] More precisely, Withdrawn in the EPO included "Deemed withdrawn", "Withdrawn" and "Disposed": in the JPO it included "Disposed", "Deemed withdrawn", "Withdrawn" and "Abandoned". Pending in the EPO includes "Undecided" and "Appealed": in the JPO it included “Undecided", "Notified" and "Appealed". Rejected in the EPO includes "Rejected": and in the JPO it included "Invalid", "Rejected", "Declined" and "Appeal refused". Granted in the EPO includes "Granted": in the JPO it included "Registered".

of striking features of the data presented in Table 2. Given our interest in the final examination outcome (i.e. grant or reject) made by the respective patent offices, the first observation to make is that there is quite a low proportion of grants and a high proportion of rejects by the JPO of patents that have been granted by the USPTO. On average across the six priority years, 44.5 per cent of patents granted by the USPTO were *granted* by the JPO, while 14.6 per cent of patents granted by the USPTO were *rejected* by the JPO. The trend in both the rate of grant and rejection by the JPO is falling: that is, over time, the JPO seems to be less likely to reject a patent granted by the USPTO, but it also seems to be less likely to grant a patent already granted by the USPTO.

Table 2: Patent Application Outcomes at the JPO, by Priority Year

Priority Year	Withdrawn[b]	Pending[c]	Rejected	Granted	Total
1990	4,653	224	2,339	7,160	**14,376**
1991	3,723	307	2,094	6,277	**12,401**
1992	3,284	475	1,976	5,279	**11,014**
1993	3,051	1,099	1,777	4,750	**10,677**
1994	3,038	2,467	1,143	4,032	**10,680**
1995	3,117	3,375	915	3,816	**11,223**
Total	**20,866**	**7,947**	**10,244**	**31,314**	**70,371[a]**
% of all applications	**29.7**	**11.3**	**14.6**	**44.5**	**100.0**
% of all examinations			**25**	**75**	**100**

Notes: [a] There were also 102 "missing" observations in the 70,473 patent family dataset which have been removed from the analysis.
[b] 96.5 per cent of those withdrawn applications at the JPO had *not* requested an examination by end 2004.
[c] 97.5 per cent of those applications still pending had requested an examination by the end of 2004.

Since in an ideal world we would expect that patent offices would come to the same decision about whether to grant or reject a given patent application, these data are alarming. Tempering our concern, however, is the very high number of withdrawn (29.7 per cent) and pending (11.3 per cent) applications at the JPO. The rate of withdrawn applications is constant over time, which suggests that there may be significant issues associated with applicant behaviour (since it is applicants who choose to withdraw or abandon an application). And there is a fairly strong increase in the rate of pendency over time, suggesting that despite our best efforts there may be truncation issues in the dataset. The last observation regarding the JPO outcomes data relates to the outcome of patent application procedures where there is a final outcome on the examination (i.e. a grant or a reject), which is presented in the last row of Table 2. When we ignore the withdrawn and pending applications, we see that the JPO rejects 25 per cent and grants 75 per cent of those patents granted by the USPTO.[20]

The patent application outcomes observed at the JPO are quite different to those at the EPO, which are presented in Table 3. The most marked difference relates to the grant and reject rates: on average across the six priority years studied, the EPO granted 72.4 per cent and rejected 3.8 per cent of the patents granted by the USPTO. Once again, the trend in the grant rates was strongly decreasing over time, while the trend in reject rates was weakly decreasing. Another major difference between the two offices was that the EPO had a much lower low average rate of withdrawn applications (3.1 per cent) compared to the JPO. The average rate of pending decisions (10.6 per cent) at the EPO was comparable to that observed at the JPO, but it seems somewhat alarming to note that there were nearly 5,000 applications at the EPO with priority years 1990 and 1991 that had not received a final examination outcome by the end of 2004. The increasing trend in pendency at the JPO suggested a truncation problem, but the observed trend at the EPO does not appear to a truncation issue: other unobserved factors may explain this observation. If we consider just the applications where a final examination decision has been made, we can see that the EPO grants 95 per cent and rejects 5 per cent of the patents granted by the USPTO.

Table 3: Patent Application Outcomes at the EPO, by Priority Year

Priority Year	Withdrawn[b]	Pending[c]	Rejected	Granted	Total
1990	475	2,703	682	10,516	**14,376**
1991	435	2,126	474	9,366	**12,401**
1992	276	1,909	399	8,430	**11,014**
1993	236	1,951	395	8,095	**10,677**
1994	382	2,475	353	7,470	**10,680**
1995	407	3,366	369	7,081	**11,223**
Total	**2,211**	**14,530**	**2,672**	**50,958**	**70,371[a]**
% of all applications	**3.1**	**10.6**	**3.8**	**72.4**	**100.0**
% of all examinations			**5**	**95**	**100**

Notes: [a] There were also 102 “missing” observations in the 70,473 patent family dataset which have been removed from the analysis.
[b] 100.0 per cent of those application withdrawn at the EPO had *not* requested an examination by end 2004.
[c] 100.0 per cent of those applications still pending at the EPO had requested an examination by the end of 2004.

[20] Another way to think of this is that we are assuming that the examination outcome of the 7,947 patent applications still awaiting a final decision will have the same grant/reject probability distribution as those where a final examination outcome has already been determined.

One issue raised by the data in Table 2 and Table 3 relates to the issue of when an applicant requests an examination and when an application is deemed to be withdrawn since it is obvious that the institutional arrangements at the different offices with regard to when an examination is conducted will have a bearing on the observed patent application outcomes. To address this issue, we have presented data in Table 4 on the number of years taken by an application in the 10th and 90th percentiles (and the median) to request an examination. Not surprisingly, the data indicates that there are substantial differences in the two offices. At the JPO, no applicants requested an examination immediately, the median applicant requested an examination by 5.75 years and the vast majority waited until the maximum period allowed (7 years). Similarly, almost all applicants who withdraw allow the application to lie pending for the maximum time and (presumably) withdraw by default. At the EPO, applicants request examination early (within 2.5 years) and are deemed withdrawn within 3 years.

Table 4: Years Between Filing Date and Withdrawal/Examination Request Dates at the JPO and EPO, 1990 to 1995

		10th percentile	Median	90th percentile
JPO				
	Withdrawn	7.23	7.27	7.31
	Exam requested	0.00	5.75	7.00
EPO				
	Withdrawn	0.70	1.27	2.83
	Exam requested	0.48	1.02	2.42

While the data on the patent application outcomes in each office provides valuable information, of more interest is the interaction of the outcomes in all three offices. To understand this, Table 5 shows a cross-tabulation of the EPO and JPO patent application outcomes (once again, conditioned on the patent being granted by the USPTO). It reveals that 37.6 per cent of US grant decisions are being affirmed by *both* of the other offices and that 0.6 per cent of applications are being clearly rejected by both offices. Moreover, it shows that 10.0 per cent of those patents granted by both the USPTO and the EPO are rejected by the JPO, while only 1 per cent of those patents granted by the by the USPTO and the JPO are rejected by the EPO. In many ways, the 2x2 matrix highlighted in Table 5 is at the heart of the patent harmonization debate, at least as it pertains to patent examination procedures and outcomes. The crux of this paper is to try and uncover the characteristics of the patents that get rejected by the JPO (or the EPO) but granted elsewhere.[21]

Table 5: Cross-Tabulation of Patent Application Outcomes, Priority Years 1990-1995[a]

	EPO				
JPO	*Withdrawn*	*Pending*	*Rejected*	*Granted*	**Total**
Withdrawn	1,339	6,831	1,401	11,295	**20,866**
(%)	*1.9*	*9.7*	*2.0*	*16.1*	**29.7**
Pending	119	1,501	144	6,183	**7,947**
(%)	*0.2*	*2.1*	*0.2*	*8.8*	**11.3**
Rejected	327	2,454	439	7,024	**10,244**
(%)	*0.5*	*3.5*	*0.6*	*10.0*	**14.6**
Granted	426	3,744	688	26,456	**31,314**
(%)	*0.6*	*5.3*	*1.0*	*37.6*	**44.5**
Total	**2,211**	**14,530**	**2,672**	**50,958**	**70,371**
(%)	**3.1**	**20.7**	**3.8**	**72.4**	**100.0**

Notes: [a] Table A1 in the appendix provides details on the breakdown of these decisions by priority year.

The other striking feature of Table 5 is that most of the applications are being lost in a haze of indecisions in one or both of the offices.[22] Specifically, of those patent applications granted by both the USPTO and the EPO, 16.1 per cent were withdrawn at the JPO while a further 8.8 per cent still had decisions pending. Similarly, 5.3 per cent of all patents granted by both the USPTO and the JPO were still "pending" at the EPO. Given our discussion above, it is reasonable to assume that a considerable portion of the still pending applications at the JPO is a direct result of the extended time granted to request and examine an application; however this is not the case for the EPO. As shown in Table 4, applicants are quick to decide whether to withdraw or pursue the application at the EPO.

[21] In another paper, Jensen and Webster (2004), we have argued that differences in patent examination outcomes across patent offices can be thought of as either a Type I or a Type II error. For example, if a patent is granted by the USPTO and the EPO but rejected by the JPO, either the JPO has rejected a patent application that *should* have been granted, or the USPTO and the EPO have granted patents that *should not* have been granted (a Type II error). It is the Type II errors that many commentators have argued have contributed to the proliferation of patent thickets in the US. However, as it turns out, it is very difficult to determine whether a Type I or Type II error has been committed.

[22] The lack of a decision in these instances is a concern for economists given the uncertainty that it creates about the existence of patent rights. Clearly, some of the decisions that are still pending after 14 years are troublesome and could be thought of as a "quasi-reject" by the respective patent offices. While those that have been withdrawn have probably been abandoned by the applicants who have realised that the marginal cost of continuing with the examination are greater than the marginal benefits. Some of these may have been granted if the examination had proceeded, while others may have been rejected.

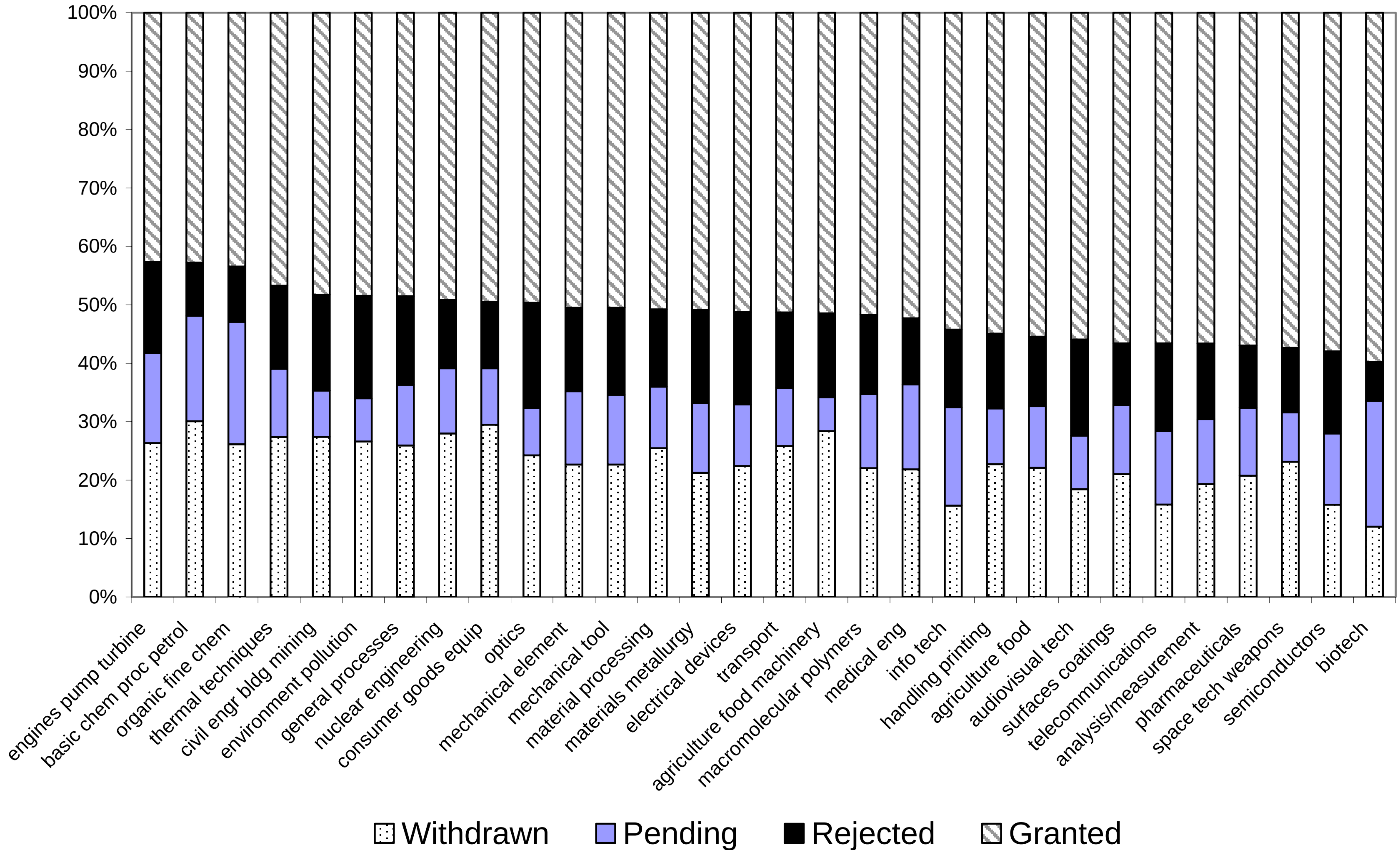
4.2 JPO application outcomes

The main conclusion from the discussion above is that there is a substantial amount of disharmony across the trilateral offices; but the disharmony appears to be centred in the JPO. This is not to say that the JPO is making mistakes in its patent examination procedures: as we have already pointed out, it is difficult to determine whether the JPO was "correct" in rejecting the 7,024 patents that were granted by the USPTO and EPO since we cannot observe the reasons for the decision to reject and nor do we have perfect knowledge of the patentability threshold. Nevertheless, it is a matter of fact that it is the JPO that seems to be in disagreement with the other two offices about which patent applications to grant and which to reject. Moreover, many of the patents granted by the USPTO and the EPO were withdrawn (or are still pending) at the JPO. As a result, we will now look more closely at the JPO decision for those applications that have been granted in both the USPTO and the EPO. This represents a total of 50,958 patents, which is 72.4 per cent of all the patents in our dataset. To get a better understanding of the nature of these patents, we have sliced this data up by technology area, number of forward citations and priority country.

Figure 1 presents a summary of the JPO patent application outcomes (conditional on being granted by the USPTO and the EPO) disaggregated into 30 OST technology groups.[23] There are some significant differences by technology area. Biotechnology had the highest grant rate (59.8 per cent), and the lowest outright reject rate (6.7 per cent), but it also had a high rate of pending decisions (21.5 per cent). Other technology areas with high rates of patent grants in the JPO were semiconductors (58.0 per cent) and telecommunications (56.6 per cent). Engine pump turbines had the lowest grant rate (42.7 per cent) and a moderately high reject rate (15.6 per cent). Optics also had both a low grant rate (49.6 per cent) and the highest reject rate (18.03 per cent). Overall, this suggests that there is substantial variation across technology areas for those patent applications where the JPO disagrees with the USPTO and the EPO.

[23] Office of Science and Technology, UK classifications. The data for the figure are contained in Table A2.

Figure 1: Patent Application Outcome at the JPO Conditional on Grant by the USPTO and the EPO, by OST Technology



Source: Table A2

The other interesting dimension of the data on patent application outcomes at the JPO is the high proportion of "non-decisions"; that is, pending applications and withdrawals. There does appear to be some differences across technology areas with regard to the rate of pending and withdrawals. For example, basic chemical processes and petroleum had a very high withdrawal rate (30.1 per cent) compared to other technology areas such as biotech (12.0 per cent). This provides additional support to the hypothesis that technology area plays an important role in patent application outcome.

Figure 2 shows the relationship between the number of forward citations and patent application outcomes at the JPO (once again conditional on the patents being granted by the USPTO and the EPO). We cut the data up into those applications with no forward citations, those with less than the median number of forward citations (which is 4), and those with greater than the median.[24] We found that higher levels of forward citations were associated with a higher probability of a decision being made (a higher grant decision but also a marginally higher reject decision) and a lower probability of being withdrawn or left pending. This provides weak support for the argument that more valuable inventions (as measured by forward citations) are more likely to be granted patents. It provides stronger support for the argument that applicants with valuable inventions are likely to make an early decision to request examination at the JPO.

Finally, we cut the data on JPO application outcomes by priority country[25] and found substantial inter-country differences. Figure 3 shows patent application outcome for priorities from Japan, Germany, the US and the rest of the world. Japanese priority applications have a much higher grant rate (69.9 per cent) in the JPO than the US (49.7 per cent), Germany (40.3 per cent) and all other countries (41.9 per cent). Moreover, Japanese priority applications have a slightly lower reject rate (12.3 per cent) by contrast with Germany (12.9 per cent) and the rest of the world (14.4 per cent). Much of the difference between Japanese applicants and the rest of the world is due to withdrawal rates which may be explained by non-Japanese applicants changing their mind about the

[24] The descriptive statistics are presented in Table A3.
[25] Priority country is highly correlated with the addresses of both the applicant(s) and inventor(s).

invention after the USPTO and EPO examination, but before having to request a JPO examination.

Figure 2: Forward Citations and JPO Application Outcomes

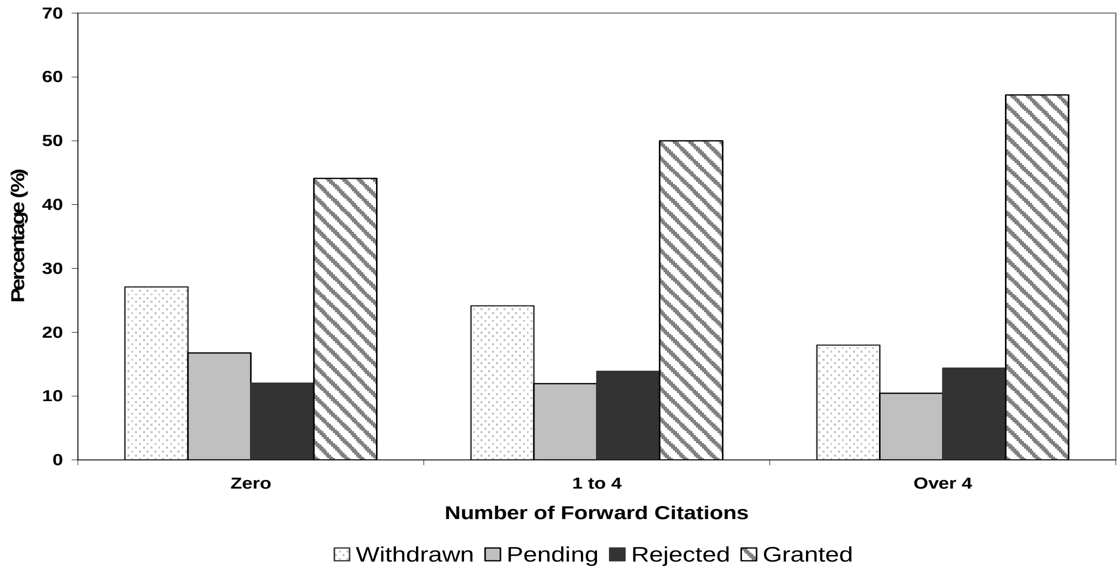
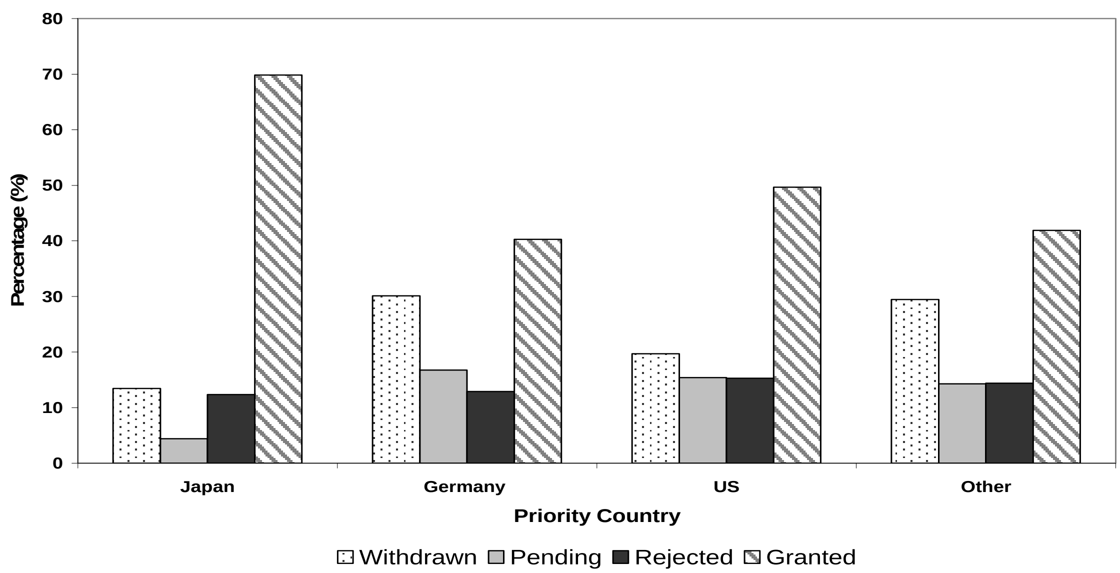


Figure 3: Priority Country and JPO Application Outcomes



5. MODELLING THE PATENT APPLICATION OUTCOMES

The descriptive data presented above suggests that there is reasonably strong evidence to assume that the disharmony in patent examination outcomes across the trilateral offices are affected by institutional delays in processing applicants, the increment in knowledge over existing art, technology area, and country of origin. Although there are numerous possible issues to study using this dataset, we have first decided to model the patent application outcomes at the JPO conditional on the patent being granted by both the USPTO and the EPO. Then we use the same model to analyse the EPO patent application outcomes conditional on the patent being granted by both the USPTO and the JPO. Other studies have modelled the EPO granting decision (see Guellec and van Pottelsberghe 2000, 2002), but none to our knowledge have studied the JPO decision in any detail.

To control for technology area, priority country and forward citations simultaneously, we have estimated the marginal effects of each patent characteristic on the probability of each possible outcome using a multinomial logit regression. To account for possible truncation in the data, we have included a dummy variable for application dates that were filed in Japan later than 1995 (accounting for 10.65 per cent of applications). This means that each application has had a clear nine years in which to achieve a decisive outcome. Denoting the possible patent application outcomes *j* for either the JPO or EPO (given the patent was granted at the other 2 offices):

$$j = \begin{cases} 3 \text{ if withdrawn} \\ 2 \text{ if pending} \\ 1 \text{ if rejected} \\ 0 \text{ if granted} \end{cases}$$

The multinomial logit model for the patent application in each office is:[26]

$$\Pr(y_i = j \mid x_i) = \frac{e^{x_x \beta_j}}{1 + \sum_{k=1}^{3} e^{x_x \beta_j}}$$

$$\text{for } j = 0,\ldots 3; \beta_0 = 0$$

where the explanatory variables in x are described in Table A4.

[26] This is under the assumption of independent and irrelevant alternatives (Greene, 2003, Chapter 21).

The results from the logit regression for the JPO, which are presented in Table 6, basically confirm the findings from the bivariate analysis discussed above. The marginal effects of technology area are presented by comparing each technology area to a base category, which we arbitrarily determined as the 'other' technology area (which includes agriculture, textiles and miscellaneous goods). *Ceteris paribus*, technology area matters in a minor but significant way.

Biotechnology applications are most likely to be granted, the least likely to be rejected, suggesting that the JPO is favourably disposed towards biotechnology patent applications. However, this may be being driven by the fact biotechnology also has the highest pending rate compared to other technology areas. So, the more speculative biotechnology applications may simply be taking longer for the JPO to make a final decision. Another interesting result from the technology area comparison are that automotive patents are least likely to result in a patent grant and are the most likely to result in a withdrawn application. Other results indicate that technology areas including software, hardware, communications, electronics and mechanical also had lower grant rates and higher outright rejection rates than the 'other' technology group.

Table 6: Marginal Effects of Patent Characteristics on Application Outcomes at the JPO

Characteristic	Outcome at the JPO			
	Withdrawn	Pending	Rejected	Granted
Area of technology				
Biotechnology (cf. other)	-0.105	0.071	-0.039	0.073
Drug (cf. other)	-0.013	0.05	-0.024	-0.012
Chemical (cf. other)	0.027	0.021	-0.008	-0.039
Software (cf. other)	-0.036	0.068	0.003	-0.034
Hardware (cf. other)	-0.03	0.053	0.012	-0.035
Communications (cf. other)	-0.035	0.03	0.019	-0.014
Electronics (cf. other)	0	0.014	0.02	-0.035
Automobile (cf. other)	0.033	0.021	0.013	-0.067
Mechanical (cf. other)	0.008	0.009	0.018	-0.035
Measures of non-obviousness				
Citation ratio ($\mu+\sigma$ cf. $\mu-\sigma$)	-0.052	-0.015	-0.008	0.075
Priority country effects				
USA (cf. Japan)	0.061	0.085	0.041	-0.186
Europe (cf. Japan)	0.15	0.083	0.027	-0.26
Other (cf. Japan)	0.116	0.049	0.051	-0.217

Finally, the country of priority continued to have a large effect on the outcome at the JPO. Being a Japanese applicant, or native speaker, appears to provide an enormous advantage. Being a US applicant (or more accurately having a US priority patent application) reduces the probability of achieving a grant by around 20 percentage points, mainly because it increases the probability of belonging to the indecisive grey-area. European sourced patents are even less successful and compared with an equivalent application from Japan; their probability of being granted is lower by 26 percentage points. Mostly this is due to a high withdrawal rate by Europeans.

We then estimated the same logit model for the patent application outcomes at the EPO; the marginal effects for this regression are presented in Table 7. Note that the sample for this logit is different to that for the JPO: this sample consists of the 31,314 patents that were granted by both the USPTO and the JPO. If we compare these results to those marginal effects at the JPO, we can draw some interesting observations. Firstly, the marginal effects for technology area on the decision to grant by the JPO were negative for all technology areas except for biotechnology: at the EPO, however, the results look more varied. There is a strong positive marginal effect for the automobile industry, for example, and weak positive marginal effects for the drug and chemical sectors. However, there is a strong negative marginal effect in the software and hardware industries and other weak negative marginal effects in biotechnology and electronics. This suggests that, similar to the situation at the JPO, there are significant differences across technology area with regard to the propensity of the EPO to grant (and reject) patent applications.

The other interesting area of comparison relates to the effects of priority country on patent application outcomes. At the JPO, it appeared that patent applications from all non-Japanese countries had a lower chance of being granted than those from Japan. A similar effect appears to occur at the EPO, but the effect is not as strong: a patent application from a European country, for example, is only 10 percentage points more likely to be granted than a patent from Japan.

Table 7: Marginal Effects of Patent Characteristics on Application Outcomes at the EPO

Characteristic	Outcome at the EPO			
	Withdrawn	Pending	Rejected	Granted
Area of technology				
Biotechnology (cf. other)	-0.003	0.023	0.004	-0.023
Drug (cf. other)	0.001	-0.009	0.003	0.005
Chemical (cf. other)	0.002	-0.006	-0.005	0.008
Software (cf. other)	0.019	0.144	0.002	-0.165
Hardware (cf. other)	0.001	0.085	0.001	-0.087
Communications (cf. other)	0	0.026	-0.005	-0.022
Electronics (cf. other)	0.003	0.026	0	-0.029
Automobile (cf. other)	0.001	-0.038	-0.017	0.053
Mechanical (cf. other)	0.002	-0.007	0.003	0.001
Measures of non-obviousness				
Citation ratio ($\mu+\sigma$ cf. $\mu-\sigma$)	-0.001	-0.007	-0.001	0.009
Priority country effects				
USA (cf. Japan)	0.01	0.025	0.012	-0.047
Europe (cf. Japan)	-0.009	-0.08	-0.013	0.102
Other (cf. Japan)	-0.002	-0.02	-0.002	0.024

6. CONCLUSIONS AND FUTURE RESEARCH

This paper has examined the application outcomes for all non-PCT patent applications with priority years 1990-1995 that were granted by the USPTO and submitted to the JPO and the EPO. The results suggest that despite the efforts of the trilateral offices (and other supporting efforts under the umbrella of patent harmonization), there is significant disharmony in the patent application outcomes across the trilateral patent offices. For instance, if we ignore the withdrawn and pending applications, the overall rejection rate for patent applications which have been granted by the USPTO was 25 per cent for the JPO and 5 per cent for the EPO. Such a difference may have important economic effects since it induces uncertainty into the ex ante investment decisions firms make with regard to innovation if they suspect that their inventions will be protected in some jurisdictions and not others. It is tempting to argue that the JPO must be making “mistakes” in its patent examination procedures. However to draw such a conclusion would be erroneous since we cannot tell whether it is the Japan that is rejecting “good” patents (Type I error) or whether the USPTO and the EPO are granting “bad” patents (Type II error).

Another insight from the paper relates to what we refer to here as a “haze of indecision”. Despite the fact that we did our best to avoid truncation problems, the number of applications for whom a decision was still pending (particularly at the EPO, where there was a high proportion of patents pending going back even to 1990) is quite alarming. Presumably, an invention that takes 14 years to acquire adequate legal protection from imitation (through acquiring a patent) is almost worthless by the time the final decision is handed down. Similar concerns can be voiced with regard to the high incidence of withdrawn applications at the JPO, which can likewise be though of as “indecisions”. In this case, much of it may be due to applicant behaviour (as they choose not to pursue examination), but some of it must also be due to the fact that the JPO, at that stage, allowed 7 years for an applicant to request an examination.

The reasons why the observed differences in patent application outcomes occur are unclear, but we have highlighted a number of possible reasons: applicant behaviour, legislative differences, institutional factors, and patent characteristics. While all of these may play a role, we have focused here on an examination of whether application outcomes vary across different observable characteristics of the patents themselves: technology area, non-obviousness and priority country. Our results suggest that the application outcomes do vary significantly across all three dimensions. Priority country appears to have a strong effect on the outcome of decisions at both the JPO and the EPO. Once again, it might be tempting to infer that the JPO and the EPO are simply using patents as a type of strategic non-tariff trade barrier. However, we cannot tell (nor do we attempt to in this paper) whether this is due to such strategic factors or whether it is just that local applicants are more familiar with the idiosyncrasies of the domestic patent system.

There are a couple of important caveats to our analysis. First, we cannot observe the individual claims in each patent application so we cannot be sure that each single, common priority patent application is for exactly the same invention. It is conceivable that during the course of the examination process in each office, the claims within the patent are modified and that the resulting patents are, in fact, slightly different. For example, it has been argued that the USPTO may allow claims narrower in scope than the other offices. To our knowledge there have been no large-scale studies to test whether this factor does vary systematically across offices. However, we do know that there is a strong correlation between the number of claims in each single, common priority patent in our dataset and are therefore confident that the patent application outcomes we are comparing here are for essentially the same invention.

Second, we cannot observe the reasons why a patent office rejects a given patent application, so we have no way of determining whether a patent rejected in one jurisdiction is a Type I error (i.e. rejecting a "good" patent). Ultimately, one of the goals of patent harmonization must be to try and ensure that all patent offices grant "good" patents and reject "bad" patents. One way in which this could determined would be to have a specialist patent attorney analyse the specifics of the patent application and see whether the patent was rejected on valid grounds. It is also possible that the Type I/Type II error distinction could be sorted out by examining the outcomes of patent litigation. It is often the case that when alleged patent infringement occurs, the courts examine patent validity and have to make a determination as to the validity of the granted patent. This is the ultimate test of a patent's validity but unfortunately doesn't provide us with much valuable information as only a small fraction of patents granted ever end up in court.

Third, the issues of sample selection bias and truncation cannot be overlooked. Despite the fact that we have attempted to overcome any potential truncation problems (through the choice of the 1990-1995 time period), it appears that there are still an alarmingly high number of patents whose examination decision is still pending (particularly at the EPO). We are not sure as to the reasons why, but we cannot discount the possibility that the bulk of these patent applications may not be distributed evenly amongst grant and reject when the final decision is handed down. We are also conscious of the possible problems associated with using a dataset based on non-PCT patents only and are currently working on developing a comparable dataset on PCT patent applications.

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8. APPENDIX

Table A1: Permutations of Non-PCT Patent Application Outcomes at the Trilateral Offices by Priority Year, 1990-1995

Priority Year	W/P	W/R	W/G	P/P	P/R	P/G	R/P	R/R	R/G	G/P	G/R	G/G	Sub-total	TOTAL
1990	1,590	380	2,386	41	10	172	537	115	1,618	535	177	6,340	13,901	**14,376**
(%) in 1990	11.06	2.64	16.60	0.29	0.07	1.20	3.74	0.80	11.25	3.72	1.23	44.10	96.70	**100.0**
1991	1,111	239	2,112	33	12	259	443	88	1,487	539	135	5,508	11,966	**12,401**
(%) in 1991	8.96	1.93	17.03	0.27	0.10	2.09	3.57	0.71	11.99	4.35	1.09	44.42	96.49	**100.0**
1992	976	204	1,914	52	9	409	387	87	1,463	494	99	4,644	10,738	**11,014**
(%) in 1992	8.86	1.85	17.38	0.47	0.08	3.71	3.51	0.79	13.28	4.49	0.90	42.16	97.49	**100.0**
1993	901	216	1,778	123	20	947	398	65	1,268	529	94	4,102	10,441	**10,677**
(%) in 1993	8.44	2.02	16.65	1.15	0.19	8.87	3.73	0.61	11.88	4.95	0.88	38.42	97.79	**100.0**
1994	1,061	167	1,624	401	50	1,974	328	45	715	685	91	3,157	10,298	**10,680**
(%) in 1994	9.93	1.56	15.21	3.75	0.47	18.48	3.07	0.42	6.69	6.41	0.85	29.56	96.42	**100.0**
1995	1,192	195	1,481	851	43	2,422	361	39	473	962	92	2,705	10,816	**11,223**
(%) in 1995	10.62	1.74	13.20	7.58	0.38	21.58	3.22	0.35	4.21	8.57	0.82	24.10	96.37	**100.0**
TOTAL	**6,831**	**1,401**	**11,295**	**1,501**	**144**	**6,183**	**2,454**	**439**	**7,024**	**3,744**	**688**	**26,456**	**68,160**	**70,371**
%	**9.71**	**1.99**	**16.05**	**2.13**	**0.20**	**8.79**	**3.49**	**0.62**	**9.98**	**5.32**	**0.98**	**37.60**	**96.86**	**100.0**

Notes: In each of the columns, the JPO decision is presented first followed by the EPO decision. “P” stands for pending; “R” stands for rejected; “G” stands for granted; “W” stands for withdrawn.

Table A2: Permutations of Non-PCT Patent Application Outcomes at the Trilateral Offices by OST Classification, 1990-1995

OST	W/G	P/G	R/G	G/G	Sub-total
electrical devices	803	377	566	1,835	3581
	22.42	10.53	15.81	51.24	100
audiovisual tech	323	160	288	978	1749
	18.47	9.15	16.47	55.92	100
telecommunications	731	579	694	2,613	4617
	15.83	12.54	15.03	56.60	100
info tech	461	496	392	1,598	2947
	15.64	16.83	13.30	54.22	100
semiconductors	210	162	187	771	1330
	15.79	12.18	14.06	57.97	100
optics	836	279	622	1,712	3449
	24.24	8.09	18.03	49.64	100
analysis/measurement	672	385	449	1,965	3471
	19.36	11.09	12.94	56.61	100
medical eng	342	227	177	818	1564
	21.87	14.51	11.32	52.30	100
organic fine chem	728	584	264	1,211	2787
	26.12	20.95	9.47	43.45	100
macromolecular polymers	545	313	335	1,277	2470
	22.06	12.67	13.56	51.70	100
pharmaceuticals	212	119	109	582	1022
	20.74	11.64	10.67	56.95	100
biotech	38	68	21	189	316
	12.03	21.52	6.65	59.81	100
materials metallurgy	304	171	228	728	1431
	21.24	11.95	15.93	50.87	100
agriculture food	69	33	37	173	312
	22.12	10.58	11.86	55.45	100
general processes	453	182	265	848	1748
	25.92	10.41	15.16	48.51	100
surfaces coatings	206	116	103	554	979
	21.04	11.85	10.52	56.59	100
material processing	585	241	304	1,166	2296
	25.48	10.50	13.24	50.78	100
thermal techniques	150	64	78	256	548
	27.37	11.68	14.23	46.72	100
basic chem proc petrol	351	211	106	499	1167
	30.08	18.08	9.08	42.76	100
environment pollution	79	22	52	144	297
	26.60	7.41	17.51	48.48	100
mechanical tool	336	177	221	748	1482
	22.67	11.94	14.91	50.47	100
engines pump turbine	381	223	225	617	1446
	26.35	15.42	15.56	42.67	100
mechanical element	389	215	246	866	1716
	22.67	12.53	14.34	50.47	100
handling printing	771	322	435	1,861	3389

	22.75	9.50	12.84	54.91	100
agriculture food machinery	69	14	35	125	243
	28.40	5.76	14.40	51.44	100
transport	552	212	276	1,096	2136
	25.84	9.93	12.92	51.31	100
nuclear engineering	98	39	41	172	350
	28.00	11.14	11.71	49.14	100
space tech weapons	44	16	21	109	190
	23.16	8.42	11.05	57.37	100
consumer goods equip	407	133	157	683	1380
	29.49	9.64	11.38	49.49	100
civil engr bldg mining	149	43	89	262	543
	27.44	7.92	16.39	48.25	100
unclassified	1	0	1	0	2
	50.00	0.00	50.00	0.00	100
TOTAL	**11,295**	**6,183**	**7,024**	**26,456**	**50,958**
	22.17	**12.13**	**13.78**	**51.92**	**100**

Table A3: Characteristics of JPO Application Outcomes Conditional on Patent Grant by the USPTO and the EPO

Variable	W/G	P/G	R/G	G/G	Total
MEASURES OF VALUE					
Forward cites (USPTO)[a]					
0 cites	2,141	1,323	950	3,484	7,898
%	27.11	16.75	12.03	44.11	100
1 to 4 cites	5,487	2,713	3,151	11,350	22,701
%	24.17	11.95	13.88	50.00	100
4 and over cites	3,632	2,111	2,901	11,543	20,187
%	17.99	10.46	14.37	57.18	100
Total	11,260	6,147	7,002	26,377	50,786
	22.17	12.10	13.79	51.94	100
COUNTRY EFFECTS					
Priority country					
Japan	1,991	650	1,826	10,352	14,819
%	13.44	4.39	12.32	69.86	100
Germany	2,690	1,496	1,153	3,600	8,939
%	30.09	16.74	12.90	40.27	100
USA	2,812	2,197	2,184	7,093	14,286
%	19.68	15.38	15.29	49.65	100
Other	3,802	1,840	1,861	5,411	12,914
%	29.44	14.25	14.41	41.90	100
Total	11,295	6,183	7,024	26,456	50,958
	22.17	12.13	13.78	51.92	100

Table A4: Variable Definitions[27]

Variable	Definition
creceive	Number of forward citations received by the granted application at the USPTO
biotech	$\begin{cases} 1 \text{ if the USPTO application has these IPC codes: A01H 1/00, 4/00;} \\ \text{A61K 38/00, 39/00, 49/00; C02F 3/34; C07G 11/00, 13/00, 15/00; C12M,} \\ \text{N, P, Q, S; G01N 27/327, 33/53,54,55,57, 68, 74, 76, 78, 88, 92} \\ 0 \text{ otherwise} \end{cases}$
drugs	$\begin{cases} 1 \text{ if Cat. code is 3 (drugs and medical) but biotech} \neq 1 \text{ (see biotech definition)} \\ 0 \text{ otherwise} \end{cases}$
chemicals	$\begin{cases} 1 \text{ if Cat. code is 1} \\ 0 \text{ otherwise} \end{cases}$
software[28]	$\begin{cases} 1 \text{ if the IPC codes are: G06F 3/, 5/, 7/, 9/, 11/, 12/, 13/, 15/; G06K 9/, 15/; H04L} \\ 0 \text{ otherwise} \end{cases}$
hardware	$\begin{cases} 1 \text{ if the IPC codes are G06; G11; H04 and software} \neq 1 \\ 0 \text{ otherwise} \end{cases}$
communications	$\begin{cases} 1 \text{ if Cat. code is 2, software} \neq 1\text{, and ict} \neq 1 \\ 0 \text{ otherwise} \end{cases}$
electronics	$\begin{cases} 1 \text{ if Cat. code is 4} \\ 0 \text{ otherwise} \end{cases}$
automobile	$\begin{cases} 1 \text{ if Cat. code is 5 and subcats 53 (Motors) and 55 (Transport).} \\ 0 \text{ otherwise} \end{cases}$
mechanical	$\begin{cases} 1 \text{ if Cat. code is 5 and automobile} \neq 1. \\ 0 \text{ otherwise} \end{cases}$
epprio	$\begin{cases} 1 \text{ if the priority country is an EPO member state.} \\ 0 \text{ otherwise} \end{cases}$
jpprio	$\begin{cases} 1 \text{ if the priority country is Japan.} \\ 0 \text{ otherwise} \end{cases}$
usprio	$\begin{cases} 1 \text{ if the priority country is the United States.} \\ 0 \text{ otherwise} \end{cases}$
otherprio	$\begin{cases} 1 \text{ if the priority country is not the US, Europe or Japan.} \\ 0 \text{ otherwise} \end{cases}$
applyyr	$\begin{cases} 1 \text{ if the application year is later than 1995} \\ 0 \text{ otherwise} \end{cases}$

[27] All of the technology variables were constructed using the IPC class of the applications filed at the USPTO (variable IPC4 in Hall et *al*., 2002).

[28] This follows Graham and Mowery (2002).