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Abstract

This paper examines the factors that cause differences in patent examination outcomes at the trilateral patent offices using a dataset of more than 70,000 non-PCT patent applications filed at the European and Japanese Patent Offices conditional upon them being granted by the United States Patent and Trademark Office. The paper finds that the quality of the invention, the applicant and whether the inventor was a local resident were the major determinants of patent grants. There is some, albeit inconsistent, evidence that examination decisions are made in the interests of the region's national trade.

JEL Classification: O31; O34; O50

Keywords: patents; patenting process; Trilateral Patent Office; innovation; invention.

1. Introduction

An invention needs to satisfy three criteria before its inventor(s) can be granted a patent: novelty, inventiveness (non-obviousness) and utility (has an industrial application).[1] These criteria form the basis of the patenting threshold which is enshrined in the legislation of all nations which are signatories to the World Trade Organization's Trade Related Aspects of Intellectual Property Matters (commonly known as TRIPS).[2] In principle, these three criteria are used to examine patent applications across the world. Thus, holding other factors constant, there should not be significant and systematic variation in the outcome of patent examinations across patent offices.

Despite this, empirical and anecdotal evidence seems to indicate that patent examination outcomes may vary across patent offices. Recent studies by Quillen and Webster (2001) and Quillen et *al*. (2002) which compared the grant rates in four different patent offices – the European Patent Office (EPO), the Japanese Patent Office (JPO), the United States Patent Office (USPTO) and the German Patent Office – found that the proportion of patent applications which are granted varied between 47 per cent in Germany and 97 per cent in the US. The existence of inconsistent patent examination outcomes across patent offices creates some concern as to the ability of a patent to provide straightforward and transparent *ex ante* incentives to invest in invention.

Unfortunately, these studies are based on aggregate patent statistics and therefore we cannot tell whether the variation in observed grant rates is due to differences in the set of applications examined by each office. That is, the use of aggregate data does not

[1] Disclosure is also often cited as the fourth criterion.
[2] These criteria, however, have been in place in most developed nations for a much longer period, but it was TRIPS, which came into force from 1 January 2005, which consolidated the inclusion of these three criteria in developed nations.

enable us to determine whether there are differences in examination outcomes *for a given invention*. Moreover, it is not possible to determine what affect other factors such as the quality of examination or applicant's behaviour have on examination outcomes. Available empirical literature suggests that both of these factors – which we refer to as "patent office behaviour" and "applicant behaviour" – may have some effect on examination outcomes.

With regard to patent office behaviour, Howlett and Christie (2003) found that variations in examination protocols may result in different patent examination outcomes.[3] Cockburn et *al*. (2002) have shown that heterogeneous patent examiners have significant effects on the breadth of patents granted and that the structure of incentives provided by the USPTO can influence the patent examination outcome.[4] While others have argued that patent offices use the patent examination decision for strategic trade reasons such as favouring local applications or applications in areas of strong national R&D activity (Kotabe 1992; Linck and McGarry 1993). With regard to applicant behaviour, Lemley and Moore (2004) have argued that the existence of "continuations" at the USPTO may provide applicants with an incentive to wear down the examiner. More anecdotally, patent attorneys often cite applicant behaviour as factor in the examination decision.

In the light of these issues, we examine the determinants of patent examination outcomes using a dataset collected between November 2004 and January 2005 of 70,000 single, common priority non-PCT patents granted by the USPTO and subject to

[3] By examination protocols, we mean the tools and techniques they use to examine non-obviousness and prior art, which we know vary across the different patent offices.
[4] Numerous commentators have raised other concerns about USPTO office behaviour including hasty examination due to insufficient resources (Farrell and Merges 2004).

examination by the EPO and the JPO.[5] By only considering single common priority patent applications, we have created a matched sample of patent applications across the trilateral offices for the same invention.[6] We then estimate the probability of granting a patent application in four separate ways in order to test the significance of factors that may have contributed towards a divergent outcome across the offices. In each model, we distinguish between factors that should affect the probability of a grant (such as the quality of the application), factors that should not affect the probability of a grant (such as strategic trade factors or persistence of an applicant) and those factors that may affect the inconsistency of examination outcomes but not necessarily the overall probability of a grant (such as the newness of the technology).

The rest of the paper is structured as follows. In section two, we discuss the determinants of patent examination outcomes which we use to formulate some testable hypotheses. Section three outlines the construction and descriptive statistics of the dataset data used and discusses the explanatory variables used. Section four identifies the general empirical model used to test the hypotheses and section five analyses the results from the four estimated models. Section six concludes.

2. Determinants of Patent Examination Outcomes

In theory, regardless of where they are filed, patent applications are granted because they satisfy the three offices' examination of their novelty, inventive step, industrial applicability, and enablement. We define the combination of these characteristics as the

[5] Ideally, we would consider applications (as opposed to grants) at the USPTO. However, for the period of the study, the USPTO only published information on granted applications. Whether or not this data limitation matters in our analysis depends on how the unobserved rejected applications at the USPTO varied systematically with our explanatory variables.
[6] There is an important caveat to this statement. Since there is substantial interaction between the applicant and the patent office which we cannot observe, it is possible that the *ex post* claims for a common priority patent granted in each office are, in fact, different.

"quality" of the underlying invention. In an ideal world, the quality of the application should be the only factor that affects the examination outcome. However, while there is little formal theory on factors affecting the examination outcome, there is anecdotal evidence suggesting that other factors influence the outcome or introduce increased dispersion into the outcome. In the following section, we group these factors according to whether they relate to patent office behaviour, to applicant behaviour or to forces that bring more uncertainty into the examination decision.

2.1 Effects of Patent Office Behaviour

Passive transmission of examination outcomes

Patent offices differ in the way in which they proceed with examining patent applications. At the USPTO, every application filed is assumed to be a request for examination, whereas at the other two offices patent applications are only examined upon request. At the EPO, the examination process is divided into two phases. The first phase of the process is a search phase meant to establish the state of the art of the invention. Then, the applicant must request a substantial examination within a 6 month period after the publication of the search report. At the JPO, applicants have seven years from the filing date to decide if they want their application examined.[7] Thus, even though we are considering the same set of patent applications claiming the same set of priority dates, there are still significant differences in the patent application filings dates, examination request dates and examination decision dates.

[7] It is no longer the case that the JPO allows 7 years in which to request an examination. This was changed in October 2001 to 3 years. However, in the period studied here, applicants did have 7 years to request examination of their patent.

Given these institutional differences in examination procedures, we would expect that the average length of time from the first filing date to the examination decision date would be the shortest at the USPTO and the longest at the JPO.[8] This lag may have a significant impact on the divergence of examination outcomes across the patent offices because the slower office may simply follow the decision of the faster office in the interest of saving resources, which we refer to as passive transmission of the examination decision. In other words, once a patent is granted in the US, other offices may simply follow their lead and "rubber stamp" their decision. In fact, we know that in some patent offices, particularly those in English-speaking developed nations, such practices are often followed. This leads us to the development of the first hypothesis.

Hypothesis 1: *The outcome of an early patent examination decision made at one patent office is passively transmitted to the other offices.*

Strategic trade factors

In a recent study, Grossman and Lai (forthcoming) argued that there are national differences in optimal patent policies and that differences in the optimal package of policy instruments includes "patent breadth" and "limits on patentability".[9] For example, the government may use its patent office to protect sectors which are important sources of innovation and export revenue. The JPO, for example, has often been accused of using patents as a non-tariff barrier (Wineberg, 1988; Linck and McGarry 1993). There are two ways in which such strategic trade behaviour may manifest themselves. First, there may

[8] This contention is confirmed by the dataset used in this paper, which is described in section 3.1.
[9] Though they only modelled optimal patent duration and enforcement, they argued that a similar set of determining factors would also determine the optimal policy instruments that a government could choose. See also Shapiro (2004).

be a simple bias towards local patent applicants over foreign applicants, as suggested in the following hypothesis.

Hypothesis 2: *For a given technology area, the probability of a patent being granted is higher for local applicants than for foreign applicants.*

Secondly, there may be more complex forms of strategic trade behaviour. Since a nation has an interest in strongly upholding patents by local companies and not recognizing patents by foreign applicants in areas of strong local R&D and innovation, it is possible that we observe differences in patent examination outcomes across the country of residence dimension and whether the technology is the dominant area of R&D expenditure. This may also be reflected in the fact that a nation has little incentive to recognize patents in areas where it manufacturers but is also a net importer of the relevant technology. We do not directly test the nuances of the latter more sophisticated hypothesis but examine the cruder version based on only absolute R&D spending. This leads us to the development of the third hypothesis.

Hypothesis 3: *The probability of grant for foreign applicants is lower if the technology area is of local strategic significance*.

While we have classified this factor as a likely office bias, we cannot be certain that local inventors or applicants are not more successful because their motivation for acquiring a local patent is stronger and therefore their behaviour is stronger in their local office.

Patent office standards

Patent offices use the same criteria to examine patent applications. However, in practice, we know that patent offices differ in how strictly they examine various dimensions of the patentability threshold. Howlett and Christie (2003) considered the examination outcomes of six hypothetical patent claims in the area of partial "DNA [Deoxyribose Nucleic Acid] sequences that constitutes EST [Express Sequence Tags]" submitted to each of the trilateral offices. Both the EPO and JPO concluded that four of the six claims failed to satisfy the inventive step requirement, whereas the USPTO passed them all.

Other reasons why examination practices may vary relate to differences in resource allocation issues across the offices, differences in the incentives provided to examiners, and administrative protocols that examiners must follow within each office. While we cannot predict *a priori* which office is the most permissive on account of these differences, we expect there could be some office-related differences which are not due to the quality of the application.

> **Hypothesis 4**: *Unobserved differences between the patent offices such as the administrative protocols and standards used to examine patent applications may lead to differences in patent examination outcomes.*

2.2 Effects of Applicant Behaviour

<u>Applicant persistence</u>

Most patent offices permit some level of interaction between the applicant and the examiner during the examination period, which may take place over several years. During this process, the applicant (or the applicant's patent attorney) has the opportunity to amend the scope of the claims to address any concerns raised by the examiner with regard to certain aspects of the claims. This suggests that the examination is not a simple process where the application is either granted or rejected: it is a more complex set of repeated interactions. In this environment, it is possible, for example, for the applicant to make an aggressive set of claims in the first instance under the expectation that they will be modified during the course of the examination process.

It is also possible that certain aspects of the examination process provide incentives for the applicant to be persistent in the interaction with the patent office, particularly if persistence is rewarded by the patent being (eventually) granted. Lemley and Moore (2004) have argued that the USPTO's system of patent continuations makes it almost impossible for a patent examiner to ever outrightly reject an application: the applicant always has a chance to respond to any concerns raised by the examiner. In a world of infinitely-repeated interactions, the examiner has a (perverse) incentive to give up objecting to the applicant's claims. Applicant persistence will vary across firm resources and prior experience with the patent office. This leads to the development of the next hypothesis.

Hypothesis 5: *Persistent applicants have a higher probability of getting a patent examination outcome in their favour.*

As previously mentioned, it is also possible that local applicants have a strong incentive to be persistent since they may value a local monopoly more than foreign applicants. They may also have more knowledge than foreign applicants about the idiosyncrasies of the local patent system and, therefore, have private knowledge about how persistence will be rewarded.

2.3 Factors Bringing Uncertainty into the Examination Decision

Speed of the technology cycle

It has recently been argued that it is more difficult to establish a uniform examination standard when the technology is changing rapidly (Lemley and Shapiro 2005). In terms of the patent threshold, the speed of the technology cycle (or technological obsolescence) makes a difference because a high rate of obsolescence can make it difficult for patent examiners to determine the size of the inventive step. That is, in areas where technology is moving very quickly, it is harder to determine whether an invention is obvious to a person skilled in the art or not. It is also possible that the speed of the technology cycle makes the search for relevant prior art more difficult since prior art may be harder to observe (especially if relevant prior art is being generated each week). These factors should have an effect on patent examination outcomes, but it is not clear whether it results in uniform effects across the offices. Thus, we argue that the speed of technological obsolescence creates divergence in patent examination outcomes across the offices in a random way.

Hypothesis 6: *The examination process for inventions exposed to faster rates of technological obsolescence is subject to more uncertainty and thus the likelihood of a divergent outcome between offices.*

Newness of technology

The newness of technology affects the clarity of the boundary around the prior arts, how well-established the scientific nomenclature is, and the ability of the office to recruit experienced examiners. These factors make it more difficult to examine both the novelty and the non-obviousness of the invention and, similar to the speed of obsolescence, they introduce uncertainty into the examination decision.

Hypothesis 7: *The examination process for inventions in newer technical areas is subject to more uncertainty and thus the likelihood of a divergent outcome between offices.*

3. Data and Explanatory Variables

3.1 Dataset Construction

The data for this study were derived 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, page 11). The triadic patent families database contains triadic patent families with priority years 1978-2003. However, in order to allow for ample examination time and minimise the amount of data truncation with regards to the examination outcome, we only use data with priority years of up to 1995. This provides approximately eight years of examination time from the claimed priority application since we did not start to pull the decision information for pending applications from the online EPO and JPO databases until late 2004.

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[10] http://www.oecd.org/LongAbstract/0,2546,en_2649_33703_30921914_1_1_1_1,00.html, visited November 2004 to January 2005.

[11] http://ep.espacenet.com/search97cgi/s97_cgi.exe?Action=FormGen&Template=ep/EN/home.hts, visited November 2004 to January 2005.

[12] http://www4.ipdl.ncipi.go.jp/Tokujitu/tjbansakuen.ipdl?N0000=116, visited November 2004 to January 2005.

[13] http://www.ipdl.ncipi.go.jp/Tokujitu/tjbansaku.ipdl?N0000=110, visited November 2004 to January 2005.

[14] http://www1.ipdl.ncipi.go.jp/SA1/sa_search.cgi?TYPE=000&sTime=1089941778920, visited November 2004 to January 2005.

In order to take into account the significant change in how one would apply for patent protection at the JPO as a result of the 1988 Japanese Patent Law reforms, we also limit our data on those which priority years begin in 1990.[15] Finally, to ensure that we only analyse examination decisions of equivalent applications across the trilateral offices, we select only patent families with a single priority application. We exclude patent families with multiple priorities because they may have multiple applications which would result in an unknown variation in the quality of the applications filed across offices.[16]

As shown in Table 1, the number of applications at the three offices over the 1990 to 1995 period ranged from 2,191,084 at the JPO to 433,186 at the EPO of which 190,583 were filed in all three offices. Eliminating PCT and multiple-priority applications leaves 70,473 applications, each of which consists of 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.

Table 1: Summary of complete patent applications in the trilateral offices, 1990-1995

Office of application	Complete patent applications/families 1990-1995
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	70,473
-multiple priorities	101,622

[15] See, for example, Sakakibara and Branstetter (2001).
[16] With a similar reason, we also drop any families involving continuation, continuation-in-parts, or divisional patent applications at the USPTO.

The second and third data sources provide information on the status of applications at the EPO and the JPO. Using the list of EPO and JPO application numbers in the triadic patent families database. All necessary information, which included 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, was downloaded from these online databases corresponding to each of the patent applications. Based on the dates collected above, we identified which applications are still pending and which have been withdrawn, rejected, or granted.[17]

Finally, we match-merged the applications data obtained from the triadic patent families database with the NBER patent database using the USPTO patent numbers (Hall, Jaffe, and Trajtenberg 2002). This provides USPTO information which is not available in the triadic patent families database such as application years, number and country of inventors, priority countries, number of claims, technology category, and number of citations made and received. Compared with all triadic patent families, our data tends to under-represent applications in the drugs and medical category (see the appendix).

3.2 Explanatory Variables

In this section, we provide a brief summary of the explanatory variables used to test the hypotheses. Table A1 and Table A2 in the appendix list and summarize the definition and

[17] 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".

the values of the variables used in the empirical models. To test the passive transmission hypothesis, we constructed three dummy variables: *Prior grant*, *Prior reject* and *Prior US grant*. The first dummy indicates if the application was granted by the other office at an earlier date. That is, when estimating the EPO decision, the "other office" is the JPO, and *vice versa*. The second variable is similarly defined, but this case in terms of a rejection. These dummy variables enables us to test the hypothesis that if the application has been granted (rejected) earlier at one office, it will have a higher (lower) chance of being granted at the later examining office. The last dummy variable indicates if the application was granted by the USPTO at a date earlier than the examination request dates at both the EPO and at the JPO.

To test whether there are any strategic trade effects on the patent examination outcomes, we constructed two types of variable: *US inventor* was included to test for possible bias for (or against) US nationals, compared with other counties. *Local inventor* is a dummy variable with a value of one if there is at least one inventor which resides in the same country as the examining office. We also constructed a series of dummies (Local Top R&D, Foreign Top R&D, Local Non-Top R&D) which were interactions between local inventor and the highest area of R&D for each office.[18] *Top R&D* indicates the technology area in which Japan (for the JPO) and France, Germany, and the United Kingdom (for the EPO) spent the most R&D in 1997 (see Table 3). In 1997, Japan spent three times as much on R&D in electrical communication instrument/machinery than

[18] It was possible to define priority country rather than the country of the residence of one of the inventors but the correlations were so high that only the *Local inventor* variable is used.

Europe.[19] The top R&D area in France, Germany, and the United Kingdom is motor vehicles.

We also needed a proxy for the quality of the patent application (over and above the fact that we are using a matched sample of patent applications). For this, we used a dummy variable of post-grant opposition at the EPO (*EPO opposed*) and the ratio of the number of citations received over the number of citations made (*Cited ratio*). [20] 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. According to Lanjouw and Schankerman (2004), more forward citations suggest that the product or process is in the initial stage of a cumulative innovation and more backward stages suggests it is in the later stages. Using a ratio also conditions for the possibility that citation rates may vary by technology area.

To measure applicant persistence, we used the number of past applications that the applicant had made to each specific office to the date of examination, as a measure of applicant's prior experience in obtaining a patent. This measure *Past apps* was derived from our dataset and thus only include past non-PCT triadic applications within the1990 to 1995 period. It will vary however by time, office and application. In addition, we include two trend variables, *Decision year* and *Application year*.

[19] National Institute of Science and Technology Policy report (NISTEP, 2001, Tables 5-1-3), based on data from OECD (1999).

[20] 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.*, revocation is more likely in new technology areas and also, but perhaps related to this, in applications where there are fewer claims.

To test the effects of heightened uncertainty on patent application outcomes, we use a set of technology-based variables. The first one is a measure of technology cycle time (*Tech cycle*) based on the measure constructed by CHI Research.[21] It is defined as the average of the median age (in years) of backward cited patents within each of the 30 OST technology categories across the period of 1980-2001. *New Technology* is an indicator for applications which fall under the biotechnology and software technological category.

3.3 Descriptive Statistics

In 2003, the trilateral patent offices granted a combined total of 351,531 patents. Of the total number of granted applications in 2003, the USPTO, JPO, and EPO granted 48, 35, and 17 per cent respectively (EPO, JPO, and USPTO, 2004). In total, these three offices accounted for 90 per cent of the world's patents in 2003.

Table 2 provides the outcome of each patent application at the EPO and the JPO. We have identified four different outcomes: reject, grant, pending and withdrawn. Keeping in mind that the total 70,473 applications shown in Table 2 have all been granted at the USPTO, the grant rates at the EPO and JPO are lower at 72.3 and 44.5 per cent respectively. For the EPO, a large minority portion of the non-granted applications are still in a pending status (i.e. under examination). For the JPO, the largest portion of such applications consists of those which have been withdrawn (i.e. an examination was not requested before the time limit).

[21] http://www.chiresearch.com

Table 2: Patent application outcomes at the EPO and the JPO

Application outcome	EPO	(%)	JPO	(%)
Granted	50,974	72.3	31,333	44.5
Rejected	2,677	3.8	10,251	14.6
Withdrawn[a]	2,212	3.1	20,879	29.6
Pending[b]	14,560	20.7	7,958	11.3
Unknown	50	0.1	52	0.1
Total	70,473	100.0	70,473	100.0

Notes: [a] 96.5 and 100.0 per cent of JPO and EPO applications respectively in this category had not requested an examination by end 2004.
[b] 97.5 and 100.0 per cent of JPO and EPO applications respectively in this category had requested an examination by end 2004.

We use data on those non-PCT patents for which a reject/grant decision has been made in both offices, which is referred to here as a "patent examination outcome".[22] In Table 3, we compare differences in the means between applications with and without local inventors in terms of whether or not the applicants have requested for (substantive) examination, the number of years between the filing date and the exam-request date, the number of years between dates the request for examination and the grant/reject decision, whether or not the granted EPO patents have ceased/lapsed in two designated countries (the United Kingdom and Germany) due to non-renewal, and whether or not the applicants have appealed any decision at the JPO.

Table 3 indicates that there are strong differences between local and foreign applicants in both the EPO and the JPO. In both offices, foreign applicants are more likely to leave a longer lag before requesting an examination (the mean difference between local and foreign applicants is -0.17 in the EPO and -0.03in the JPO). Similarly, there is a substantial difference in the lag in the number of years it takes the patent offices to reach a decision for a local applicant versus a foreign applicant. In the EPO, the mean

[22] We draw a distinction between "patent examination outcomes" and "patent application outcomes", which also include those patent applications which were withdrawn or are still pending. For an analysis of the withdrawn and pending patent applications, refer to our separate work (Jensen *et al.*, 2005).

difference in the decision lag was -0.50 years, while in the JPO the decision lag was -0.35 years. This raw data suggests that there are reasons to support the contention that there are either local biases in the patent offices, or that patent applicant behaviour varies by nationality, or both.

Table 3: Differences in applicant filing and processing behaviour, EPO and JPO

	Mean		Mean Difference
	Local	Foreign	(Local – Foreign)
EPO			
Exam requested	0.98	0.96	0.02
Request lag (years)	1.00	1.17	-0.17
Ceased in GB/DE	0.12	0.11	0.01
Decision lag (years)	3.13	3.63	-0.50
JPO			
Exam requested	0.84	0.67	0.17
Request lag (years)	4.30	4.33	-0.03
Appealed	0.09	0.07	0.02
Decision lag (years)	2.56	2.91	-0.35

Note: This tabulation is based on all 70,473 applications.

Table 4 presents data on the characteristics of the patent applications at the EPO and the JPO by examination outcome and explanatory variable. The data indicate that 3,414 patent examination outcomes related to patents in new technology areas (biotechnology and software); 87.8 per cent of which were granted. Other interesting observations from this table are that 8.6 per cent of the 24,290 patent examination applications made by local inventors were rejected compared with 14.5 per cent of foreign applicants and that 15.3 per cent of the 19,184 patent applications made by US inventors were rejected by the other offices. Finally, the data suggest that a high proportion (41.3 per cent) of those applications with a prior reject were rejected by the other patent office, although this is based on a small number of observations (276).

Table 4: Characteristics of patent application by examination outcome

Characteristic of application		Percentage rejected	Percentage granted	Percentage examined	Total number examined
New technology area	yes	12.2	87.8	100.0	3,414
	no	12.4	87.6	100.0	65,790
Local inventor	yes	8.6	91.4	100.0	24,290
	no	14.5	85.5	100.0	44,914
US inventor	yes	15.3	84.7	100.0	19,184
	no	11.3	88.7	100.0	48,866
Local inventor - top R&D area	yes	9.6	90.4	100.0	10,080
	no	12.9	87.1	100.0	58,914
Foreign inventor - top R&D area	yes	15.5	84.5	100.0	13,830
	no	11.6	88.4	100.0	55,164
Local inventor - other R&D area	yes	7.8	92.2	100.0	14,210
	no	13.6	86.4	100.0	54,784
Prior grant	yes	29.6	70.5	100.0	12,439
	no	8.7	91.4	100.0	56,765
Prior reject	yes	41.3	58.7	100.0	276
	no	12.3	87.7	100.0	68,928
Prior grant in US	yes	18.8	81.2	100.0	32,507
	no	6.8	93.2	100.0	36,697

Note: The total number of patent applications examined at both the EPO and JPO was 69,204.

Technology area is also an important characteristic of the patents. In Table 5, we have provided a breakdown of the proportion of patents granted by technology area. As already mentioned, biotechnology and software are classified as new technology areas. Biotechnology has the highest proportion of patents granted (91.3 per cent) while other mechanical has the lowest proportion (86.6 per cent).

Table 5: Percentage of patents granted by primary technology area

Primary technology area	Percentage granted	Total examined
Biotechnology	91.3	630
Hardware	87.7	7,626
Software	87.0	2,784
Automobile	87.2	3,958
Chemicals	88.3	14,616
Communications	87.5	4,472
Drugs	88.9	3,336
Electronics	86.7	14,914
Other mechanical	86.6	10,046
Other	88.6	8,904

The characteristics of the other remaining explanatory variables are presented in Table 6. Granted applications tended to have a higher cited ratio and be associated with applicants who had less prior experience with the respective patent office. Furthermore, more recent applications were less likely to be granted than earlier applications. We now turn to formally model and estimate the hypotheses provided in section 2.

Table 6: Average characteristic of patent application by examination outcome

Characteristic	Rejected	Granted	Total
Tech cycle - mean age (years) of backward citations	9.8	9.6	9.7
Cited ratio	1.38	1.57	1.55
Opposed in EPO – JPO examination outcome only	0.04	0.04	0.04
Past triadic applications by same applicant (to the same office)[a]	240.3	200.2	205.2
Decision year (1987=1)	11.2	9.3	9.5

Note: [a] These are only for applications in our dataset and accordingly are limited to single priority, non-PCT applications made during 1990 to 1995. Only ‘past’ applications made before the date of examination are recorded for each application.

4. The General Empirical Model

We assume that the decision to grant application *i* should depend solely on the quality of the invention, *q*, and therefore any remaining unexplained part of the decision will result either from systematic biases in the examination process associated with patent office behaviour, *o*, applicant behaviour, *a*, or random error, *ε*. Systematic biases include whether the office is influenced by prior decisions in the US and the other office;

preferences towards or behaviours of local inventors or applicants; and whether the application, which has been filed by a local applicant, is in an area of strategic national interest. Accordingly, if y is the examination outcome:

$$y^* = q + f(o,a;\beta) + \varepsilon \tag{1}$$

$$y_i = \begin{cases} 1 \text{ if } y^* > 0 \text{ (application is granted)} \\ 0 \text{ if } y^* \leq 0 \text{ (application if rejected)} \end{cases}$$

where o and a denote vectors of explanatory variables which represent patent office and applicant biases in the examination decision with β as their associated vector of parameters to be estimated. Assuming $\Pr(y^*_i > 0 \mid q_i, o_i, a_i) = \dfrac{\exp\begin{bmatrix} o \\ a \end{bmatrix}_i' \beta}{1 + \exp\begin{bmatrix} o \\ a \end{bmatrix}_i' \beta}$, equation (1) can be estimated as a binary logit model (Greene, 2003, Chapter 21).[23]

We estimated (1) in four ways. In the first and second models, we estimate equation (1) separately for both the EPO and the JPO, and include the ratio of forward to backward cites, and whether opposed at the EPO (for JPO applications) as a measure of q and the number of past applications the applicant has previously lodged with each office as a measure of a. Since we cannot jointly estimate the effects of a bias to local applicants overall with national strategic considerations, the first model includes a local inventor dummy variable, while the second model includes a set of technology variables interacted with the local inventor dummy.

Since we cannot be sure that these models adequately control for quality, the third model pools the data and treats q as a random effect (the unit is the application) and

[23] Alternatively, one may want to follow Guellec and van Pottelsberghe (2000) and estimate equation (1) as a binary probit model.

explicitly regresses the explanatory variables including using the number of past applications per applicant as a measure of *a.* Similarly, we cannot be sure that we have adequately controlled for applicant behaviour in the previous models, so the fourth model also pools the data but this time treats *a* as a fixed effect (the unit is the applicant). *q* is once again proxied by the ratio of forward to backward patent citations. However, this model can only be estimated with applicants who filed multiple applications during our data period, and accordingly, it was estimated on a smaller sample compared to the preceding estimations.

5. Results and Analysis

5.1 Model 1 – Separate Office Estimation with Simple Local Inventor Effect

The estimated equation for each patent office was:

$$y^*_i = \beta_q q_i + f(o_i, a_i; \beta) + \varepsilon_i \qquad (2)$$

where *i* represents the patent family. Table 7 presents the estimations of the separate office equations using the *Cited ratio* and *EPO opposed* to control for the quality of the application, *Past apps* to control for applicant behaviour and a dummy variable for *Local inventor*. Only those applications which had been examined in both EPO and JPO are included. The columns for the EPO model and the JPO model represent the coefficients, their statistical significance and the estimated marginal effects of the explanatory variables.

First of all, earlier decisions at other jurisdictions seem to be important only at the JPO. For example, on average, applications which have been rejected at the EPO when the JPO begins its examination process have 23.97 percentage points lower likelihood of being granted by the JPO. The likelihood is also lower at the EPO, however it is of a much smaller magnitude and is not statistically significant. However, applications which have been granted in the US when either the EPO or the JPO begins its examination are not more likely to be granted in any of these two offices. Another surprising result is shown by the effects of earlier decision (grant) at the EPO, which is opposite to our expectation. Patent applications which have been granted by the EPO at earlier dates have slightly less than 3 per cent points of lower probability of grant at the JPO. Unfortunately, we do not know of any definite explanation for this seemingly counter-intuitive finding.

The results on inventor bias in the patent offices suggest that an overall preference or advantage for local applicants is supported. At the JPO, the probability of a grant for patent applications with a Japanese inventor is 5.86 percentage points higher than those without. For the EPO, the effect is smaller, at 1.32 percentage points, perhaps signifying a potential language or cultural effect at the JPO. There is also reasonably strong evidence to suggest that both the EPO and the JPO are biased against US inventors since both offices are more likely to reject patents where at least one inventor is from the US.

Past applications was incorrectly signed suggesting no evidence that applicant persistent has any effect on patent examination outcomes. To test the hypothesis that there are inherent office differences in the processes and protocols, we estimated a model similar to equation (1) – not reported here – using pooled applications data examined by the EPO and the JPO and allowing for the regression coefficients to vary between the two offices by including interactions with a dummy variable with a value of one if the decision comes from the EPO and zero other wise. The results indicate that most of the interaction terms are statistically significant indicating that the effects of the determinants do vary across offices. Finally, the ‘Hit and Miss’ percentages of correctly predicted applications, rose from 94 under random assignment, to 97 for the EPO, and from 66 to 79 for the JPO.[24]

Table 7: Coefficient estimates and marginal effects, EPO and JPO, Model 1

Determinants	EPO Decision				JPO Decision			
	Coeff.	SE	dy/dx		Coeff.	SE	dy/dx	
QUALITY EFFECTS								
EPO opposed					-0.0759	0.0736	-1.17	
Cited ratio	0.0175	0.0104	0.05	*	0.0343	0.0058	0.52	***
OFFICE EFFECTS								
Prior grant	0.3940	0.3925	0.88		-0.1677	0.0393	-2.57	***
Prior reject	-0.5788	0.4758	-2.05		-1.1808	0.1488	-23.97	***
Prior US grant	0.0182	0.0760	0.05		0.0600	0.0406	0.91	
US inventor	-0.7491	0.0792	-2.38	***	-0.1049	0.0361	-1.61	***
Local inventor	0.5268	0.0911	1.32	***	0.4008	0.0352	5.86	***
APPLICANT EFFECTS								
Past apps.	-0.0004	0.0001	-0.00	***	-0.0000	0.0000	-0.00	
Constant	4.1514	0.1391			2.9523	0.0755		
OTHER EFFECTS								
Decision year	-0.1298	0.0194	-0.35	***	-0.1972	0.0075	-2.98	***
Application year	0.1442	0.0283	0.39	***	0.1331	0.0105	2.01	***
log(likelihood)	-4565.7				-15470.4			
pseudo-R^2	0.0394				0.0526			
Prob[Grant]	0.9725				0.8146			
sample size	33242				32543			
Hit & Miss								
- under random assignment	94%				66%			
- from this model	97%				79%			

*** (significant at 1% level), ** (significant at 5% level), * (significant at 10% level)
Note: The base group consists of applications which have been granted at the USPTO at a date sufficiently later than any substantive examination at the EPO or JPO, are classified as other technology (Category 6), do not have any local inventor, and have received no post-grant oppositions at the EPO.

5.2 Model 2 – Separate Office Estimation with National Strategy Effect

The estimated equation for each office was the same as Model 1:

$$y^*_i = \beta_q q_i + f(o_i, a_i; \beta) + \varepsilon_i \qquad (3)$$

[24] Under random assignment, we estimate the asymptotic number of estimated grants and rejects if each application was subject to the same random probability of being granted as the overall grant rate. In the case of the EPO, we assume that each application has a 97 per cent chance and being granted. The percentage of correct predictions is made by comparing this with the actual grant and reject status.

but we replaced *Local inventor* with interaction terms between technology area and nationality of inventor to enable us detect possible strategic trade effects.

Table 8: Coefficient estimates and marginal effects, EPO and JPO, Model 2

Determinants	EPO Decision				JPO Decision			
	Coeff.	SE	dy/dx		Coeff.	SE	dy/dx	
QUALITY EFFECTS								
EPO opposed					-0.0997	0.0739	-1.55	
Cited ratio	0.0183	0.0104	0.05	*	0.0381	0.0059	0.57	***
OFFICE EFFECTS								
Prior grant	0.4052	0.3925	0.90		-0.1860	0.0394	-2.85	***
Prior reject	-0.5902	0.4762	-2.09		-1.2038	0.1492	-24.50	***
Prior US grant	0.0178	0.0761	0.05		0.0586	0.0406	0.89	
US inventor	-0.7547	0.0794	-2.38	***	-0.0995	0.0362	-1.52	***
Local Top R&D	0.8197	0.1483	1.68	***	0.1977	0.0466	2.86	***
Foreign Top R&D	0.0864	0.0795	0.22		-0.1309	0.0366	-2.02	***
Local Non-Top R&D	0.4125	0.1052	0.99	***	0.4893	0.0442	6.73	***
APPLICANT EFFECTS								
Past apps.	-0.0004	0.0001	-0.00	***	0.0000	0.0000	0.00	
OTHER EFFECTS								
Decision year	-0.1272	0.0195	-0.34	***	-0.1949	0.0075	-2.94	***
Application year	0.1412	0.0284	0.38	***	0.1304	0.0105	1.96	***
Constant	4.1156	0.1423			2.9762	0.0760		
log(likelihood)	-4561.9				-15448.8			
pseudo-R^2	0.0402				0.0539			
Prob[Grant]	0.9726				0.8151			
sample size	33242				32543			
Hit & Miss								
- under random assignment	94%				66%			
- from this model	97%				79%			

*** (significant at 1% level), ** (significant at 5% level), * (significant at 10% level)
Note: The base group consists of applications which have been granted at the USPTO at a date sufficiently later than any substantive examination at the EPO or JPO, are classified as other technology (Category 6), do not have any local inventor, and have received no post-grant oppositions at the EPO.

As can be seen from Table 8, JPO applications with local inventors received an advantage if they are in the top R&D technology areas, as expected. However, the size of this advantage is smaller than the advantage given to local applicants in 'non-top' R&D areas. On the contrary, foreign inventors have a significantly lower probability of grant in the JPO if their applications are in 'top' technology areas compared with the base case (foreign non-top and the local inventors). Similarly at the EPO, local inventors with applications in the top R&D area are more likely to have their applications granted compared with local inventors in non-top areas and all foreign applicants. This represents some, but not overwhelming, support for hypothesis 3. Finally, the increment to predictive accuracy for the hit and miss tables were the same as for model 1.

5.3 Model 3 – Quality Random-Effects Model

The models discussed above cannot guarantee that we have fully controlled for the inherent quality of the invention. To do this, we model the quality of the application as unobserved heterogeneity in a random-effects model.[25] Because we are pooling data across offices we are able to include a dummy variable for the office decision (JPO) to detect whether there is a systematic tendency for the JPO to have stricter examination standards than the EPO overall, or vice versa. However, since *US Inventor,* and *Application year* do not vary by office, they are not explicitly modelled but included in the q.

The estimated equation for the pooled data was:

$$y^*_{ip} = q_i + f\left(o_{ip}, a_{ip}; \beta\right) + \varepsilon_{ip} \qquad (4)$$

where p represents the office. It was estimated as a random-effects logit regression and the results are presented in Table 9. An important contribution of these estimates are see how accounting more carefully for quality alter the coefficients from model 1. The signs on the variables which reflect the presence of passive transmission from prior grants in the other office was negative corroborating our doubts about the strength of this effect.

[25] We chose a random-effects model since the fixed-effects model only includes applications where there was a grant-reject or reject-grant decision and this lead to a considerable selection bias in our data.

However, the effect of a prior US grant or a prior reject in the other office were correctly signed and significant and considerably larger in magnitude than model 1 (and 2).

Table 9: Coefficient estimates and marginal effects, Model 3

Determinants	Grant Decision			
	Coeff.	SE	dy/dx	
OFFICE EFFECTS				
Prior grant	-1.85	0.04	-24.27	***
Prior reject	-2.14	0.16	-36.12	***
Prior US grant	0.23	0.03	1.81	***
JPO	-1.36	0.04	-11.43	***
Local inventor	0.96	0.03	7.00	***
APPLICANT EFFECTS				
Past apps.	-0.00	0.00	-0.00	***
OTHER EFFECTS				
Decision year	0.31	0.01	2.4	***
log(likelihood)	-24,297.76			
Prob[Grant|0 fixed effects]				
Rho	0.17	0.02		
No. groups	34,602			
No. observations	68,503			
Hit & Miss				
- under random assignment	79%			
- from this model	87%			

*** (significant at 1% level), ** (significant at 5% level), * (significant at 10% level)
Note: The base group consists of applications which have been granted at the USPTO at a date sufficiently later than any substantive examination at the EPO or JPO, are classified as other technology (Category 6), do not have any local inventor, and have received no post-grant oppositions at the EPO.

As in model 1, the effect of being a local inventor had a positive and significant effect. In model 1, being a local inventor increased the probability of a grant between 1 to 6 percentage points. In model 3, however this was 7 percentage points. In addition, and not surprisingly, the JPO was found to have an across the board lower grant rate, of 11.43 percentage points, and there has been a negative decline in the propensity to grant patents over time. Finally, the sign on the accumulated number of past applications by the applicant firm was still negative and significant which further discounts our hypothesis that more experienced applicants have better examination success.

5.4 Model 4 – Applicant Fixed-Effects Model

So far, we have tried to capture the applicant behaviour effect by including as a variable the applicant's past record of patent applications. However, this variable is unlikely to fully capture the broader dimensions of applicant behaviour such as persistence, determination and latitude. Accordingly, we have undertaken a number of further steps to scrutinize more closely systematic effects of applicant behaviour. The first step has been to model applicant behaviour as unobserved heterogeneity in a fixed-effects model.

The estimated equation for the applicant fixed-effects model was:

$$y^*_{ij} = \beta q_i + a_j + f(o_{ij};\beta) + \varepsilon_{ij} \qquad (5)$$

where j represents the applicant. This equation was estimated as a fixed-effects logit estimation and are presented in Table 10. Similar to model 3, comparing the size of the coefficients with model 1 gives us an indication of how important applicant effects are vis-à-vis patent office effects.

As expected, Table 10 reveals that the local inventor effect is greatly reduced but this can be explained by the close correlation between the country of residence of the applicant and the inventor. The US inventor effect was considerable larger in the EPO but similar in the JPO. It would appear that office bias against US inventors is greater in the EPO but the overall success rate in the EPO is moderated more persistent US applicants. Comparing model 4 with model 1, we find a greater uniformity of the coefficient on prior reject from the other office. The 'pure' office effect of a prior reject in both offices leads to a 7 to 9 percentage fall in the probability of a grant. This suggests that the greater apparent sensitivity of the JPO to a prior rejection at the EPO, may in fact be due to applicant behaviour, not office behaviour. A rejection at the EPO still seems to have a perverse effect at the JPO for reasons we cannot explain.

Table 10: Coefficient estimates and marginal effects, EPO and JPO, Model 4

Determinants	EPO Decision				JPO Decision			
	Coeff.	SE	dy/dx		Coeff.	SE	dy/dx	
QUALITY EFFECTS								
EPO opposed					-0.1605	0.0939	-1.96	*
Cited ratio	0.0444	0.0197	0.83	***	0.0404	0.0078	0.52	***
OFFICE EFFECTS								
Prior grant	1.3339	0.7334	30.80	*	-0.2080	0.0516	-2.63	***
Prior reject	-0.4499	0.6613	-7.47		-1.0783	0.1951	-9.49	***
Prior US grant	-0.2065	0.1122	-3.80	*	0.1331	0.0538	1.68	**
US inventor	-0.5644	0.2847	-10.02	**	-0.0902	0.1032	-1.15	
Local inventor	-0.0559	0.2947	-1.04		0.1366	0.1819	1.78	
OTHER EFFECTS								
Decision year	-0.1565	0.0287	-2.93	***	-0.2179	0.0120	-2.81	***
Application year	0.1053	0.0420	1.97	**	0.1472	0.0157	1.90	***
log(likelihood)	-1739.9				-8404.7			
Prob[Grant|0 fixed effects]	0.2498				0.1519			
Number of observations	11370				20642			
Number of groups	323				1107			

*** (significant at 1% level), ** (significant at 5% level), * (significant at 10% level)
Note: The base group consists of applications which have been granted at the USPTO at a date sufficiently later than any substantive examination at the EPO or JPO, are classified as other technology (Category 6), do not have any local inventor, and have received no post-grant oppositions at the EPO.

To summarise so far, while a considerable portion of the grant decision at both offices appears to be guided by the quality of the application, there is evidence for both office and applicant biases. In particular, there is a systematic positive effect of being a local inventor in both offices. However we do not know whether this is due to office preferences or applicant pushiness. The JPO appears to have higher examination standards across the board, *ceteris paribus*. There are also grounds for believing that more tenacious, avid or determined applicants are also more likely to receive a grant, *ceteris paribus*.

In the next section we examine the data for evidence that the discord in the grant decision between offices was greater for new technologies compared with more established ones, and for technologies with faster rates of obsolescence.

5.5 Factors Increasing Uncertainty into the Examination Decision

To test for whether applications in the technology areas most prone to uncertainty had the most divergence decision making, we estimated 'hit and miss' tables from the models 1 and 3 and disaggregated these by whether the application was in a new or established technology, and by the obsolescence speed of the underlying technology area. Results from this exercise are presented in Table 11. These show that there is no consistent tendency for applications in the new technologies to have more 'unexplained' grants than in established technologies (the opposite appears to be the case). Furthermore, technologies that have a faster speed of obsolescence appear to have better rates of prediction rather than worse as we would expect *a priori*.

In summary, we find no compelling evidence that applications in either new technologies or those experiencing faster technology cycles are subject to greater unpredictability in decision making.

Table 11: Percentage of correct predictions, Models 1 and 3

	Model 1		Model 3
	EPO	**JPO**	
Random assignment – all data	94%	66%	79%
Model predictions			
– all data	97%	79%	87%
– new technology	95%	81%	95%
– established technology	97%	78%	87%
– speed of obsolescence			
- fast	97%	82%	88%
- medium	97%	79%	87%
- slow	97%	75%	85%

6. Conclusion

This papers looks at the determinants of patent examination outcomes at the trilateral offices. Unlike Guellec and van Pottelsberghe (2002), the focus of the paper is on how the decision making process in the EPO and JPO differ. The empirical exercise is based on a newly constructed data set of more than 70,000 non-PCT patent applications filed in the three trilateral offices: the EPO, the JPO and the USPTO.

The paper finds that for this set of matched applications, the examination decisions at both the EPO and the JPO depended both on factors that should affect the decision, that is, the quality of the invention, and factors that should not affect the decision, that is, applicant behaviour and office preferences towards local inventors or applicants. There was no evidence of greater randomness in the decision making over applications in either new technologies or faster developing technologies. On average, the JPO appear to have higher examination standards than either the EPO or the USPTO. There is some, albeit inconsistent, evidence that national strategic examination decisions are made.

Prior to this study, little attempt has been made to explain the existence of the observed cross-country/region variation in patent examination outcomes while controlling for the objective quality of the underlying invention (see Lerner 2002). This is rather surprising given the recent debate on international harmonization of patent policy. Given the directive for patenting is essentially the same across offices, examination inconsistency is evidence that at least one office must be making an incorrect decision: examination standards are too high or too low either across the whole office or between types of applicants.

The finding that there is a significant applicant effect is of concern. Granting a patent to an invention that does not pass the grade on objective quality merely encourages applicants to pursue their anti-competitive motives. Firms who desire to use patent blocking (Cohen *et al.,* 2000) as a strategy for enhancing their profits will find patent offices unwitting accomplices for their rent-seeking activities. It is well-known, however, that the construction of patent thickets may a deleterious effect on the competitiveness of R&D and innovation more generally (see Shapiro 2001, for example).

A few caveats in interpreting the findings include possible truncation and sample selection problems and, perhaps the most important, the use of a reduced form model. The truncation problem comes from the fact that we only consider applications which have been given an examination decisions, ignoring the facts that an application for patent is time-continuous process from the filing date until the decision/withdrawal date. That is, the paper only looks at granted/rejected applications and ignores the withdrawn/abandoned or pending ones.[26] The sample selection problem may arise from our use of applications filed at each trilateral office which did not use the Patent Co-operation Treaty (PCT) route. However, during the time frame we are considering, only 10 per cent of trilateral applications used the PCT route. Nonetheless, it remains that we cannot conjecture what kind of truncation and sample selection bias, if any, may result and thus leave these issues for future studies.

[26] See Jensen et al. (2005) for our first attempt at analysing pending and withdrawn applications at the JPO.

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8. Appendix

Table A1: Variable definition and test hypotheses[27]

Variable	Definition
Granted	$\begin{cases} 1 \text{ if the EPO (JPO) grant date is filled (or later than reject date)} \\ 0 \text{ if the EPO (JPO) reject date is filled (or earlier than grant date)} \end{cases}$
Prior grant	$\begin{cases} 1 \text{ if the EPO (JPO) grant date} < \text{the JPO (EPO) exam request date} \\ 0 \text{ otherwise} \end{cases}$
Prior reject	$\begin{cases} 1 \text{ if the EPO (JPO) reject date} < \text{the JPO (EPO) exam request date} \\ 0 \text{ otherwise} \end{cases}$
Prior US grant	$\begin{cases} 1 \text{ if the US grant date} < \text{EPO (JPO) exam request date} \\ 0 \text{ otherwise} \end{cases}$
Cited ratio	Cite received / cite made at the USPTO
Speed of obsolescence	Average median years of backward cited patent within the technology class
Biotechnology	$\begin{cases} 1 \text{ if the USPTO application has these IPC codes: A01H 1/00, 4/00;} \\ \text{A61K 38/00, 39/00, 49/00; C02F 3/34; C07G 11/00, 13/00, 15/00;} \\ \text{C12M, N, P, Q, S; G01N 27/327, 33/53,54,55,57, 68, 74, 76, 78,} \\ \text{88, 92} \\ 0 \text{ otherwise} \end{cases}$
Software[28]	$\begin{cases} 1 \text{ if the IPC codes are: G06F 3/, 5/, 7/, 9/, 11/, 12/, 13/, 15/;} \\ \text{G06K 9/, 15/; H04L 9/} \\ 0 \text{ otherwise} \end{cases}$
New technology	Biotechnology & software
Local inventor	$\begin{cases} 1 \text{ if any inventor's country of residence is an EPO member state} \\ \text{(Japan).} \\ 0 \text{ otherwise} \end{cases}$
EPO opposed	$\begin{cases} 1 \text{ if the application received a post-grant opposition at the EPO.} \\ 0 \text{ otherwise} \end{cases}$
Decide year	The year of the decision (grant or reject) at the EPO (JPO), 1990=1
Apply year	The year of the filing of the application at the EPO (JPO), 1990=1

[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). The technology categories (Cat. codes) referenced in this table were taken from Table 9 of Hall *et al.* (2002).
[28] This follows Graham and Mowery (2002).