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Gaétan de Rassenfosse
Paul Jensen
T'Mir Julius
Alfons Palangkaraya
Elizabeth Webster

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Is the patent system a level playing field? The effect of patent attorney firms

Gaétan de Rassenfosse
Ecole polytechnique fédérale de Lausanne, Lausanne, Switzerland
gaetan.derassenfosse@epfl.ch

Paul H. Jensen
The University of Melbourne, Melbourne, Australia
pjensen@unimelb.edu.au

T'Mir Julius
The University of Melbourne, Melbourne, Australia
tdjulius@unimelb.edu.au

Alfons Palangkaraya
Swinburne University of Technology, Melbourne, Australia
apalangkaraya@swin.edu.au

Elizabeth Webster
Swinburne University of Technology, Melbourne, Australia
emwebster@swin.edu.au

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Abstract

The patent system underpins the business model of some of the fastest-growing companies. Used appropriately, it should support frontier technologies and nurture new firms. Used perniciously, it can stifle innovation and protect established technological behemoths. We analyse patent examination decisions at the American, European, Japanese, Korean, and Chinese patent offices and find evidence that patent attorney firms have a surprisingly large role in the patent system. Patent attorney firm quality is most important, vis-à-vis invention quality, in less codified and more rapidly changing technology areas such as software and ICT. Moreover, patent attorney firm quality matters more when invention quality is low. Finally, there is a significant inter-patent office variation, with a greater patent attorney firm quality effect at the USPTO.

JEL codes:

Keywords: appropriation; innovation; patent attorney firm; patent system

1. INTRODUCTION

Innovation, a significant driver of productivity growth, is supported by various policy tools, including R&D grants and subsidies, tax incentives, and the patent system. A patent system is a controversial tool since it offers a temporary monopoly right on inventions in exchange for (the hope of) greater private investment in R&D activities. Scholars theorise how to set the broad parameters of the patent system to best drive a nation's innovative potential. However, business scholars have been quick to point out the association between the concentration of economic power in the dominant technological giants—Facebook, Amazon, Apple, Microsoft, and Google—and the size of their patent portfolios.[1] Policy bodies try to strike a balance between legal and economic recommendations and the vested interests of lobby groups of various kinds—the *realpolitik* of the patent system.

In theory, a patent monopoly right should only be granted if it plays a pivotal role in the decision to invent, develop, and market a product. This pivotal role is thought to occur when the subject idea is highly inventive relative to existing ideas. To improve the alignment between this theory and practice, policymakers have focused on raising patent quality by reducing loopholes that allow less inventive ideas to gain a patent.[2] However, the patenting process is a highly technical matter, leaving ample room for gaming the system.

In this paper, we explore empirically a hitherto unexamined influence on the patent examination decision that may drive a wedge between the optimal and actual outcomes: the influence of the patent attorney firm (PAF).[3] The PAF acts on behalf of the inventor, or their employer, to convince the government (as represented by its patent office examiners) that the invention is worthy enough to grant the inventor/employer a legal, temporary exclusion right. We contend that a 'high-quality' PAF might be able to get a grant for a 'low-quality' patent application (*i.e.,* one that has a low chance of being socially valuable). To the extent

[1] The patent portfolios of these companies range from about 3,000 to 90,000. See discussions in Anson (2018) and Haskel and Westlake (2107).

[2] In recent decades, national governments have enacted changes to their patent systems to raise the required inventive step threshold, reducing the probability of injunctions for infringement, sharing information across offices, and introducing faster and cheaper courts. These changes aim to maximize the likelihood that low-quality patent applications are weeded out of the system (either by the patent office or the courts).

[3] Our study also contributes to the recent literature on law firm expertise (Krishnan and Masulis 2013, Krishnan *et al*. 2016, 2017, Bates *et al*. 2018, Westbrock *et al*. 2019); innovation (Griliches 1990); firm innovation and its market value (Hall *et al.* 2007, Nicholas 2008, Simeth and Cincera 2016); and firm behavior and intellectual property holdings (Griffith *et al.* 2014, Chen *et al.* 2016, Bena *et al*. 2017).

that this occurs, we suggest that it might represent a welfare loss to society since granting monopoly rights comes with a cost.

To estimate the impact of the PAF on examination outcomes, we construct an estimating sample consisting of about 100,000 patent applications filed in at least three of the IP5 offices during the period 2000–2006. The IP5 offices are the European Patent Office (EPO), the Japanese Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the National Intellectual Property Administration of China (CNIPA, formerly SIPO) and the United States Patent and Trademark Office (USPTO). For our analysis, we construct proxies for the unobserved invention quality and PAF quality by employing high-dimensional fixed-effects models (Abowd *et al.* 1999, Guimaraes and Portugal 2010) based on the population of 1.2 million IP5 patent applications. By construction, a higher value of each proxy is associated with a higher probability of grant in the patent examination decision.

Our results suggest that the patent system is *not* an even playing field. We confirm the importance of PAF even after we control for invention quality. We find that PAF 'quality' matters more at the USPTO than invention quality for obtaining a grant. Furthermore, we find that PAF quality is less critical in highly codified technologies such as chemicals/pharmaceuticals and more critical in less codified or newer/more rapidly changing technologies such as ICT and software. Moreover, PAF quality is more important when invention quality is low.

Our findings have possible welfare implications. For example, it is likely that some inventions that should have been granted a patent were refused because PAFs did not do a good job, and vice-versa. In that sense, the stronger the PAF's importance relative to the importance of the invention quality, the more the patent system departs from its optimal design *ceteris paribus*. However, the existence and magnitude of any welfare loss crucially depend on the complex matching process of high/low quality patent applications with high/low quality PAFs, which we know little about. Furthermore, they also depend on other factors that could correlate with PAF such as the quality of the disclosure. Therefore, we refrain from making any definitive welfare conclusions.

The next section provides background on the role of PAFs and summarises the main forces affecting the patent examination outcome. Section 3 outlines the empirical strategy. Section 4 describes the data. Section 5 presents the baseline results and extends the analysis to account for the interaction between PAF quality and invention quality. Section 6 concludes.

2. BACKGROUND

Patents are legal rights designed to provide pecuniary incentives for people to invest in non-excludable and non-rivalrous 'creations of the mind.' The grantee receives a temporary right to exclude others from exploiting their idea, thus enabling the grantee to earn a (temporary) higher price. It is well-known that these monopolies amount to static inefficiencies, but economists tolerate this distortion, provided that the deadweight loss is offset by the dynamic efficiency created by encouraging invention (Arrow 1962, Nordhaus 1969). These static monopoly costs can be substantial as inventions are non-rivalrous goods. Nonetheless, improving this static-dynamic trade-off is at the heart of better and more effective innovation systems.

More recently, it has been found that patent systems can also transmit dynamic inefficiencies. Scholars have documented that patents can also be used as an anti-competitive weapon to lock out would-be competitors from certain technological spaces (Bessen, 2003; Rubinfeld and Maness, 2005; von Graevenitz, Wagner and Harhoff 2013; Hall, von Graevenitz, and Helmers, 2021; among others). Others have given considerable space to designing a patent system that encourages innovation but minimizes this rent-seeking behaviour (*e.g.*, Merges 1999; Shapiro, 2004; Scotchmer 2004; Jaffe and Lerner 2007).

Inventors wishing to obtain the legal right to stop others from using their idea will hire a PAF (for a fee, which we do not observe here) to draft and prosecute a patent application. PAFs vary in size, quality and fees, and the inventor will select the PAF that best suits their needs and budget. The definition of PAF used here includes specialized patent attorney firms as well as other patent prosecution practitioners including large law firms who provide specialised patent prosecution advice to their clients as part of a diversified portfolio of services such as tax and contract advice. To add further complexity to the situation, inventors employed in a large firm may also use an in-house patent attorney to conduct the patent prosecution which we attempt to account for in our analysis. Given the specialized technologies underpinning the patent application, PAFs are typically organized around key areas (*e.g.*, chemicals) and different PAFs will have different strengths and reputations.

Once the client has selected the PAF, through a decision-making process that is unobserved here, the PAF will assign the patent application to an individual patent attorney (or a team) in the firm who is skilled in the relevant technical area (typically, they will have a PhD in that area) and will write the patent application to highlight the invention's novelty, utility, and inventiveness. The PAF then submits the application to a patent office in every jurisdiction where the applicant wants to claim monopoly privileges. If the applicant wants a patent in a foreign jurisdiction, in almost all cases the PAF will get an attorney firm that is local to this jurisdiction to prosecute the application process.[4]

Once the patent application has been submitted to the patent office(s), it will then be allocated quasi-randomly to a patent examiner skilled in the relevant art. The examiner then scrutinises the application to see if it meets the patentability criteria of novelty, utility and non-obviousness. This 'patent prosecution' process may take many years—and cost thousands of dollars—involving many iterations and compromises between the prosecuting PAF and the patent examiner.[5] As the assessment of patent worthiness is difficult and usually protracted, there is room for the patent attorney to influence the examiner (Langinier and Marcoul 2016).[6] There is also evidence suggesting the existence of 'revolving doors' between PAFs and patent offices. Tabakovich and Wollman (2018) show that USPTO examiners may trade off lax patent examinations for the possibility of future employment.

If patent examiners' decisions are not aligned with consistent standards of novelty, utility, and non-obviousness, the power of a patent system to stimulate innovation is diminished (Merges 1999).[7] Although there has been a stream of work identifying examination loopholes, recent

[4] Europe, through the European Patent Office, is treated as a single jurisdiction.
[5] Although patent attorneys receive instructions from their clients, attorneys are usually in charge of drafting the patent document and orienting the direction of patent examination (Glazier 2000).
[6] The importance of this bilateral negotiation is evidenced by a geographical concentration of Japanese patent attorney firms around the JPO because attorneys need face-to-face communication with patent examiners as they negotiate the drafting of their patent applications (Reiffenstein 2009). In addition, recently released office action data from the USPTO of more than 2 million patent applications filed in 2008-2017 show that virtually every applicant had to respond to a non-final rejection office action from the examiners (Lu *et al.* 2017).
[7] Empirical research has uncovered several such inconsistencies *e.g.*, the importance of examiner characteristics (Cockburn *et al.* 2002, Lemley and Sampat 2012, Kim and Oh 2017, Tabakovic and Wollmann 2018, Righi and Simcoe 2019), applicant behavior (Palangkaraya *et al.* 2008, Harhoff and Wagner 2009, Webster *et al.* 2014), and

work by Schankerman and Schuett (2017) has demonstrated that patent offices are still not effective at weeding out low-quality patent applications. However, the role of the PAF in such outcomes is still unknown.

We contribute to this stream of work by considering the impact of the PAF (also known as a patent practitioner in the United States) on the patent grant decision vis-à-vis the inventive step of the invention (which we call 'invention quality').[8] We seek to quantify the nature and magnitude of PAF's influence on patent examination outcomes. For this, we need a measure of the 'quality' of the attorney (where quality indicates experience, skill, expertise, and the power of persuasion). Ideally, we would observe quality at the individual attorney level, but our data only permit us to observe collections of attorneys in the form of patent attorney firms. Hence, our unit of analysis is the PAF that conducts the patent prosecution (observed closest to the time of patent grant).[9]

PAF quality may affect the examination decision directly or in combination with other factors. Although almost all PAFs conducting the patent prosecution reside in the same country as the patent office, some are in-house attorneys, and others are external (public) attorneys contracted to prosecute the patent application through the examination process.[10] It is plausible that external attorneys (accounting for 97% of our sample) could be less effective in assessing and arguing for the patentability of the inventions than in-house attorneys. They have less access to the scientists and engineers who invented the technology, making for a less nuanced patent specification (see also Somaya *et al*. 2007). PAF quality is also likely to be more critical in technology areas that are newer or experiencing rapid progress and therefore have fuzzier technological boundaries. In contrast, technologies such as electrical and chemical/pharmaceutical—which are relatively highly codified—should offer a more limited scope for the attorney to influence the examination outcome. Indeed, the relevant prior art in more established technologies is better known and more accessible, implying that

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examination timing (Frakes and Wasserman 2017, Kovács 2017). See also Eckert and Langinier (2014) and Bessen and Meurer (2008).

[8] As far as we can ascertain, there has been very little prior interest in the role of patent attorneys (Reitzig 2004 and Suzeroglu-Melchiors *et al.* 2017 are notable exceptions).

[9] Of course, inventors can change PAFs during the course of the prosecution process. However, this is not observable to us in a systematic manner.

[10] Our dataset shows that close to 100 percent of patent attorney firms are 'local' to the office of application. In some jurisdictions, such as Japan, it is compulsory to use a local patent attorney firm.

establishing novelty is theoretically easier than for emerging technologies. Furthermore, examiners are more experienced with established technologies such that there is potentially more consensus about the non-obviousness criterion.

The effect of the PAF may also depend on the filing route used. Prosecuting multi-nation patent applications by filing a single application under the Patent Cooperation Treaty (PCT) is more straightforward than filing patent applications individually to each patent office via the 'Paris route.' The former involves filing the priority patent application at any member office of the PCT and designating an international search authority to perform the preliminary search report on the invention's patentability. By contrast, the Paris route involves filing individual patent applications in each office where protection is desired, with minimal coordination between offices. Therefore, the PCT application route reduces the complexity faced by patent applicants (and their attorney firms) and may improve the chance of obtaining a grant decision.

Of course, other factors may affect patent application outcomes besides attorney firm and invention quality, which we should control for in a model. For example, there is evidence of discrimination against foreign applicants at the EPO and JPO (Webster et *al.* 2014) and CNIPA (de Rassenfosse and Raiteri forthcoming). Any such bias may be mitigated using a higher quality PAF.

3. IDENTIFICATION STRATEGY

Estimating the impact of patent attorney firm quality holding invention quality constant

We specify an estimating equation based on patent examiners' decision to grant or reject the application based on their assessment of the inventiveness of the underlying invention. The assessed inventiveness, y_{ik}^{o*} in equation (1) below, is a latent variable. We assume it to be a function of the underlying but unobserved invention quality (ν_i), the quality of the PAF (which is also unobserved, but we use a proxy measure of it denoted as $\hat{a}_k$), and other observable invention, office, and PAF-specific factors (z_{ik}^{o}) that may affect grant over and above invention and PAF quality:

$$y_{ik}^{o*} = f([\hat{a}_k, z_{ik}^o]'\boldsymbol{\beta}) + \nu_i + \varepsilon_{ik}^o, \ \ i \in S_1 \tag{1}$$

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

where the unit of observation is a patent application for invention i prepared by PAF *k* and filed and examined in patent office *o*. The other observables (z_{ik}^o) include whether the invention is of a local inventor, the use of the multi-nation or PCT application route, whether the PAF was an external provider rather than in-house patent attorney, the technology area, and the applicant. The observed dependent variable (y_{ik}^o) in equation (1) is a binary indicator of whether the patent application prosecuted by PAF *k* for a given invention i and examined by patent office o is granted. S_1 denotes the main estimating sample as will be further discussed below.

The interpretation of the main parameter of interest in equation (1) is complicated by the fact that it is plausible that there is an unobserved sorting mechanism: a higher quality invention is assigned a higher quality PAF and that, simultaneously, a higher quality invention is more likely to be granted a patent. Therefore, to identify any causal relationship between PAF quality and patent examination outcome, we need to control for variation in the quality of the underlying invention (which is unobserved by the econometrician). In our main analysis, we control for invention quality by implementing fixed-effect (within patent family) regressions utilizing data on patent applications that sought protection in multiple jurisdictions. The term 'invention family' denotes an invention applied to multiple patent offices.[11] This identification strategy is similar to the one used in Webster *et al.* (2014) to identify the causal relationship between local inventor status and patent examination outcome.

Unlike Webster *et al.* (2014)'s local inventor status which is observable and exogenous, our key variable (PAF quality) is unobserved and subject to the plausible sorting mechanism correlated with the 'invention family' effect. Therefore, to estimate equation (1), we first construct a proxy for PAF quality that is orthogonal to ν_i. We use a high-dimensional fixed effects approach to address the potential endogeneity between invention quality and PAF quality when constructing our proxy for PAF quality ($\hat{a}_k$). Specifically, we construct $\hat{a}_k$ by

[11] More formally, we define a family as a set of patent applications that protect the same invention in at least one other jurisdiction where each subsequent filing claims a one-to-one priority link with a focal priority filing.

estimating the following panel linear probability model with two fixed effects where the subscripts are as defined in the text:

$$y_{ik}^{o*} = a_k + \nu_i + \epsilon_{ik}^{o}, \;\; i \in S_2 \qquad (2)$$

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

where $i \in S_2$ indicates that the sample of patent families used to estimate equation (2) is independent of the sample used to estimate equation (1). The estimated fixed effects of a_k in equation (2) are the proxy for PAF quality in equation (1), which we denote as $\hat{a}_k$.[12]

We obtain the subsamples S_1 and S_2 by randomly splitting the full sample of patent application families: the first half, denoted S_1, is used for estimating the main model (equation 1), and the second half, denoted S_2, is used for constructing the PAF quality proxy ($\hat{a}_k$) based on the LPM estimates of equation (2).[13] In splitting the sample, we ensure that no family is split across the two subsamples to avoid creating an arbitrary correlation between $\hat{a}_k$ and y_{ik}^{o} in equation (1). That is, our measure of PAF quality is not a function of the invention quality of the estimating sample.[14] The split-sample approach in the construction of our proxy measure of PAF quality is necessary to avoid the trivial (spurious) relationship between $\hat{a}_k$ and y_{ik}^{o} (the dependent variable in equation 1).

Some further discussion of the statistical assumptions behind the estimation of the PAF fixed effect in equation (2) is warranted. Consistent with the existing literature, we assume that PAF quality (a_k) and invention quality (ν_i) are uncorrelated with the error term (ϵ_{ik}^{o}). It is not particularly clear how likely it is that the first assumption holds in the presence of an

[12] Alternatively, as generously pointed out by an anonymous referee, we could have instead used a similar strategy as discussed for equation (2) to specify and estimate our main equation (1) as a model with two fixed effects ($y_{ik}^{o*} = f([z_{ik}^{o}]'\boldsymbol{\beta}) + a_k + \nu_i + \varepsilon_{ik}^{o}$). We can then analyse the predicted PAF and invention quality fixed effects ($a_k; \nu_i$) to address our original research questions. However, we believe the proxy variable approach facilitates for a more direct analysis of the effect of PAF quality on patent examination outcome and the analysis of its interaction effects and single office estimation (in which, as detailed in the discussion of equation (3) below, we have to a have a proxy measure of invention quality constructed in a similar way as the PAF quality proxy).

[13] Even after splitting the sample, we still have variation from over 9,000 PAFs and over 200,000 invention families to obtain our estimates of the main parameters of interest.

[14] To account for the possibility that a patent applicant may exist in both subsamples and employ the same PAF, which may lead to a violation of this assumption, we test the robustness of our analysis to the inclusion of applicant fixed effects in equation (1).

invention-attorney match effect. To see this, we draw on Card *et al*. (2013)'s extension of Abowd *et al.* (1999), to think of the error term ϵ_{ik}^{o} in equation (2) as consisting of three random-effects components: (i) an invention-attorney firm match component (η_{ik}), (ii) an invention-specific, patent office varying component (ω_{ik}), and (iii) a pure idiosyncratic individual invention outcome component (ζ_{ik}). We argue that if the invention-attorney firm match component is driving a correlation between a_k and ϵ_{ik}^{o}, it essentially reflects an unobserved applicant effect because it is the applicant who does the sorting.[15] To test this possibility, we include an applicant fixed-effect in a robustness analysis of our model. Since the inclusion (or exclusion) of this fixed effect does not change the estimated coefficient of PAF quality, we conclude that it does not alter our findings.[16] In addition, the invention-specific, patent office varying component (ω_{ik}) does not appear to be important. Such an effect could be important if different patent offices had different patent examination parameters that vary by fields of technology and language. We confirm that these factors are unimportant by including local inventor effect and technology specific effects in our regressions.

Comparing the impact of *PAF quality and invention quality*

Differencing out invention quality (ν_i) in a fixed-effect framework as specified in equation (1) allows us to isolate the impact of PAF quality. However, it does not allow us to analyse the relative importance of PAF quality and invention quality. For this purpose, we estimate a slightly different model where we use an invention quality proxy ($\hat{v}_i$) constructed in a similar way to the construction of the attorney quality proxy ($\hat{a}_k$):

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[15] As an analogy to the employer-employee analysis, we can imagine the case where the parents (in our case, the applicants) of the employee (in our case, the invention) also own the employer or the establishment (in our case, the patent attorney firm). In such a case, the parents determine the matching.

[16] In our base model (equation 1), because we observe the same invention (patent) in up to five different patent offices, we can use invention (patent) level fixed effects to control for sorting between invention quality and PAF quality. This assumes that the sorting is closely related to the unobserved quality of invention regardless of the patent office (jurisdiction) of filing. That is, if a given applicant chooses a higher quality PAF for a higher quality invention when filing for patent at the USPTO, then they will do the same when filing for patent at other patent offices. It is plausible that our assumption above does not hold if the applicant has a different sorting strategy depending on the office of filing. For example, for unobserved reasons, an applicant may regard a certain office to be more important than others. To assess the effect of this possibility on our estimates, we extend our base model by incorporating applicant fixed effects on the assumption that the strategy is consistent across different inventions/patents of the same applicant. We thank one of the referees for suggesting that we examine the average number of PAFs used by an application in order to explore this possibility. We found that, on average, applicants only use two distinct PAFs in each of the patent offices (the median firm only uses one PAF) and that the chosen PAFs are of relatively similar quality. Indeed, the average standard deviation in the quality of an applicant's PAFs is half of the overall standard deviation of PAFs. For details, please contact the fourth author.

$$y_{ik}^{o*} = f([\hat{a}_k, \hat{v}_i, z_{ik}^o]'\boldsymbol{\beta}) + \varepsilon_{ik}^o, \quad i \in S_1 \tag{3}$$

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

To construct $\hat{v}_i$ we use a similar strategy by splitting the sample along the office dimension. That is, for any given office o, we construct $\hat{v}_i$ as the conditional grant rate in all other offices. For example, if $o = USPTO$, then $\hat{v}_i$ is the conditional grant rate at EPO, JPO, KIPO, and SIPO where the conditional grant rate is obtained from fixed-effect models similar to equation (2) using sample in the non-focal patent office.[17]

4. DATA AND DESCRIPTIVE STATISTICS

Estimating sample

The estimation sample comes from the population of applications with one-to-one equivalents in at least two of the IP5 offices (priority years 2000–2006), which correspond to 1,264,735 patent applications relating to 461,961 invention families. All these applications had been examined.[18]

After randomly splitting the sample into two subsamples (about 600,000 each), dropping families with unknown/missing attorney code, dropping PAFs (and the associated families of patent applications) that handled fewer than two applications (for PAF quality proxy construction) and keeping families with applications that have been examined in at least three offices, our main estimating sample (S_1) contains families corresponding to about 100,000 inventions (for a total of nearly 300,000 patent applications).[19]

Sample descriptive statistics

[17] Because the maximum panel size for each invention is only four, our fixed effect estimates of invention quality (v_i^*) may be inconsistent due to 'small T' problem in the panel regression. In the implementation, we assess how our estimates of $\boldsymbol{\beta}$ specified in equation (1a) below (and presented in Table 3 in the results section) change when we implement the Correlated Random Effects model (Mundlak 1978, Chamberlain 1982, Wooldridge 2010, 2019, Elzinga and Gasperini 2015). The results, not reported but available on request, confirm that our estimates derived from fixed effect regressions are robust to the possible bias arising from the small T dimension in the patent family panel data.

[18] In Appendices A and B, we provide further details on the data construction and the identification of PAFs.

[19] Randomly splitting the sample several times would yield different sets of estimating samples. As discussed later, we assess the sensitivity of our analysis to different random splitting of the sample by conducting 100 different random splits. Our results are robust to the use of different random splits.

Table 1 provides a descriptive summary of estimating sample S_1 in terms of key variables and for each family size classification. It shows that the proportion of granted applications ranged from 0.770 at the JPO to 0.970 at CNIPA. The proportion of applications with a local inventor was 0.359; using an external PAF was 0.976; and using the PCT route was 0.181. Most applications were in the technology areas of ICT, mechanical engineering, and electrical.

Table 1. Descriptive summary of invention family, priority years 2000–2006

VARIABLES	Panel LPM Sample (N = 278,738)		Binary logit panel sample (N = 79,298)	
	Mean	Std. Dev.	Mean	Std. Dev.
Grant (1 if granted; 0 if refused/XY withdrawn)	0.873	0.333	0.592	0.491
EPO	0.818	0.386	0.469	0.500
JPO	0.770	0.420	0.283	0.450
KIPO	0.907	0.290	0.700	0.458
CNIPA	0.970	0.171	0.899	0.301
USPTO	0.929	0.257	0.775	0.417
PAF quality (Index = attorney fixed effect)	-0.068	0.142	-0.082	0.163
Local inventor (1 if a local inventor; 0 otherwise)	0.359	0.480	0.343	0.475
External (1 if use external attorney; 0 otherwise)[20]	0.976	0.154	0.969	0.176
PCT (1 is use PCT route; 0 other)	0.181	0.385	0.186	0.389
Biotech (1 if biotech patent; 0 other)	0.007	0.082	0.009	0.093
ICT (1 if ICT patent; 0 other)	0.222	0.416	0.250	0.433
Software (1 if software patent; 0 other)	0.058	0.233	0.069	0.253
Electrical (1 if electrical patent; 0 other)	0.219	0.414	0.216	0.411
Instruments (1 if instruments patent; 0 other)	0.168	0.374	0.174	0.379
Chemical/Pharma (1 if chem/pharma; 0 other)	0.056	0.231	0.062	0.242
Process engineering (1 if proc. eng.; 0 other	0.080	0.272	0.080	0.271
Mechanical engineering (1 if mech. eng; 0 other)	0.204	0.403	0.173	0.378

5. RESULTS

Table 2 presents the results from estimating equation (1).[21] It shows that the PAF quality has a positive and significant effect on the probability of getting a patent even when we control for applicant fixed effects in the last column of Table 2.[22] Furthermore, noting that the PAF

[20] To identify whether a patent attorney was in-house or not, we estimated the number of applicants each attorney had represented in our dataset. If an attorney had had only one client, we deemed in an in-house attorney (this was 2.8% of our sample). As such, this approximation will overstate the number of in-house attorneys.

[21] We use bootstrapped standard errors without clustering because the level to cluster is unclear. One may argue the error terms are correlated within the same invention, applicant, PAF, patent office, technology, or other. To see if our standard error estimates (and thus our analyses) are robust to different possible correlation structures of the error terms, we re-estimate our main model presented in Table 2 under different clustering options. Results show that our main estimate (the effect of attorney quality) is remarkably robust to correlation in the error terms in various forms (contact the fourth author for details).

[22] The third column is estimated using the "reg2hdfe" command in STATA which allows for two high-dimensional fixed effects but is limited to only a linear panel regression model.

quality measure is normalised, the OLS estimates imply that a one-standard-deviation increase in attorney quality is associated with a seven percentage-point increase in the grant probability. The corresponding figure for the logit estimate is about twelve percentage points. Note that a higher figure for the logit estimate compared to OLS is not surprising because the logit regression model only exploits observations from families with mixed outcomes.

Table 2. Average marginal effect on grant probability at the IP5 offices (invention family fixed effect model), priority years 2000–2006

Method:	**OLS**	**Logit**	**OLS**
PAF quality	0.070***	0.123***	0.069***
	(0.001)	(0.003)	(0.002)
Local inventor	0.055***	0.100***	0.052***
	(0.002)	(0.003)	(0.003)
PCT filing	0.007**	0.010	0.009*
	(0.003)	(0.007)	(0.005)
External attorney	0.013**	0.029**	0.012*
	(0.005)	(0.012)	(0.005)
Constant	0.811***		
	(0.005)		
Invention family fixed effect	Yes	Yes	Yes
Patent office fixed effect	Yes	Yes	Yes
Applicant fixed effect	No	No	Yes
N-applications	278,738	79,298	268,188
N-invention families	108,135	28,969	103,022
R-sq. / Log-likelihood	0.079	-18975.6	0.487

Note: PAF quality and invention quality are normalized to mean = 0 and standard deviation = 1. () = bootstrap standard errors; ***/**/* statistically significant at 1/5/10 per cent respectively. Dependent variable: Grant = 1 if granted; 0 if refused.

As argued in Section 3, using invention family fixed effects implies that we cannot make any inference about the relative importance of invention quality vis-à-vis PAF quality. Table 3 addresses this concern and presents estimates for equation (3). As described above, data from each of the other four IP5 offices are used to construct invention quality proxy ($\hat{v}_i$) using a panel fixed-effect logit regression with patent family as the fixed effect.

The results reveal two main insights. First, PAFs have a significant effect at all offices. The average marginal effect of attorney quality is highest at the EPO (5.1 percentage points), followed by the JPO (3.9 percentage points) and the USPTO (3.6 percentage points). As we z-standardise the quality measures, these logit marginal effect estimates mean that a one-standard-deviation increase in PAF quality is associated with the shown percentage-point increase in the probability of grant. Second, the standardisation of the invention and PAF quality measures enables direct comparison of the relative effects. As Table 3 shows, PAF quality is more important than invention quality at the USPTO, which is the only office where we observe this pattern.

Table 3. Average marginal effect on grant probability at each office, Logit estimates, priority years 2000–2006

Office:	**USPTO**	**EPO**	**JPO**	**KIPO**	**CNIPA**
PAF quality	0.036***	0.051***	0.039***	0.020***	0.011***
	(0.001)	(0.002)	(0.002)	(0.003)	(0.002)
Invention quality	0.004***	0.063***	0.073***	0.051***	0.012***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)
Local inventor	0.019***	0.071***	0.101***	0.053***	0.017***
	(0.003)	(0.005)	(0.004)	(0.004)	(0.006)
PCT filing	-0.066***	0.067***	0.014***	0.092***	0.022***
	(0.004)	(0.005)	(0.005)	(0.004)	(0.002)
External attorney firm	-0.012	0.010	0.019	-0.050	-
	(0.009)	(0.010)	(0.014)	(0.033)	
Technology fixed effect	Yes	Yes	Yes	Yes	Yes
Applicant fixed effect	No	No	No	No	No
N-applications	40,367	26,454	40,122	19,437	30,341
Pseudo-R2	0.127	0.151	0.059	0.089	0.084

Note: PAF quality and invention quality are normalised to mean = 0 and standard deviation = 1. () = bootstrap standard errors.; ***/**/* statistically significant at 1/5/10 per cent respectively. Regression estimates are based on separate regression of each patent office's decision. Dependent variable: Grant = 1 if granted; 0 if refused (and, for EPO, withdrawn with EPO XY citation). Estimation method: Logistic regression model.

Given the United States' international role in technological markets, Table 4 investigates the nature of the PAF effect at the USPTO more closely using the specification in equation (3). The estimations use all observations within the estimating sample (S_1) of 40,367 patent families examined at the USPTO (columns 1 and 2) as well as within the sub-samples according to the family size (columns 3–5).

The parameter estimates of interest appear to be insensitive to the size of the family (columns 3–5) and applicant or examiner fixed effects (columns 6 and 7). Compared to PAF quality, invention quality at the USPTO is a less important determinant of grant as revealed by the size of the respective coefficients. The average marginal effect of invention quality is only about one tenth that of PAF quality and appears to be insensitive to the same sample/model variation considered. Note that our sample only includes applications made by repeat applicants to multiple offices; it is biased towards higher-quality inventions from large PAFs. Therefore, we expect that the PAF quality effects would be larger if the tail of low-quality inventions and smaller firms were modelled.

Table 4. Average marginal effect on grant probability at the USPTO by family size, priority years 2000–2006

	All family sizes	**All family sizes**	**Family size (N_f)**			**Applicant FE†**	**Examiner FE‡**
			$N_f = 5$	$N_f = 4$	$N_f = 3$		
PAF quality	0.058***	0.036***	0.041***	0.036***	0.034***	0.063***	0.041***
	(0.002)	(0.001)	(0.004)	(0.002)	(0.002)	(0.005)	(0.002)
Invention quality	0.007***	0.004***	0.009**	0.005***	0.003*	0.006***	0.008***
	(0.001)	(0.001)	(0.004)	(0.002)	(0.001)	(0.001)	(0.001)
Local inventor	0.004	0.019***	0.021	0.027***	0.015***	0.004	-0.005
	(0.003)	(0.003)	(0.016)	(0.006)	(0.004)	(0.009)	(0.008)
PCT filing	-0.073***	-0.066***	-0.094***	-0.056***	-0.066***	-0.047***	-0.015***
	(0.003)	(0.004)	(0.012)	(0.007)	(0.005)	(0.007)	(0.004)
External attorney	-0.002	-0.012	-0.032	-0.026*	-0.006	0.012	-0.015*
	(0.007)	(0.009)	(0.034)	(0.015)	(0.011)	(0.015)	(0.008)
Constant	0.958***					0.936***	0.947***
	(0.007)					(0.017)	(0.010)
Technology fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Applicant fixed effect	No	No	No	No	No	Yes	Yes
Examiner fixed effect	No	No	No	No	No	No	Yes
Method	OLS	Logit	Logit	Logit	Logit	OLS	OLS
N-applications	40,367	40,367	3,698	12,423	24,232	39,852	29,671
Adj./Pseudo/Overall R2	0.081	0.127	0.192	0.114	0.131	0.073	0.352

Note: PAF quality and invention quality are normalized to mean = 0 and standard deviation = 1. () = bootstrap standard errors.; ***/**/* statistically significant at 1/5/10 per cent respectively. Dependent variable: Grant = 1 if granted; 0 if refused.
†There are 5,229 unique applicants; the fixed effects account for 48.1 percent of the variance. ‡Estimated using STATA's reghdfe command

Robustness analysis

Some further discussion about how the different extent of measurement errors in our proxy variables for invention quality ($\hat{v}_i$) and PAF quality ($\hat{a}_k$) could drive the results summarised above is warranted. It is plausible that the dominant PAF quality effect shown in Table 4 is a result of our proxy measure for invention quality having a higher dispersion than our proxy measure for PAF quality.[23] In fact, because we construct the invention quality fixed effect regression using a significantly shorter 'time' dimension (*i.e.*, at a maximum of only four offices) than the 'time' dimension of the PAF fixed effect regression (which could be in the

[23] We thank an anonymous referee for raising this point.

thousands of patent applications), the invention quality proxy would have intrinsically higher error variance than the PAF quality proxy.

To assess whether the higher error variance of invention quality proxy relative to PAF quality proxy drives our finding in Table (4) we first note that, as summarised in Table (3), even though the shorter 'time' dimension of the invention quality fixed effect regression is true for all offices, PAF quality is only more important than invention quality at the USPTO. Thus, it is unlikely that higher error variance of invention quality proxy drives the result in Table 4.

Notwithstanding this consideration, as we do not know how severe our measurement error problem could be, we re-estimated equation (3) for the case of USPTO using STATA's error-in-variable regression command *eivreg*. This method allows us to assess the influence of measurement errors by estimating how large the errors in the invention quality proxy must be to flip our conclusion. The results are summarised in Table (5) below, in which we assume different degrees of reliability for invention quality. As can be seen, even at a degree of reliability of 0.25 (which is equivalent to three-quarters of the variation in the invention quality proxy arising from measurement errors), there is still evidence that PAF quality is more important than invention quality at the USPTO.

Table 5: OLS estimates for USPTO (comparable to the OLS results in Table 4)

	Degree of reliability of invention quality proxy			
	1.0	**0.75**	**0.50**	**0.25**
PAF quality	0.058***	0.058***	0.058***	0.059***
	(0.002)	(0.002)	(0.002)	(0.002)
Invention quality	0.007***	0.010***	0.015***	0.031***
	(0.001)	(0.002)	(0.003)	(0.005)
N-applications	40,367	40,367	40,367	40,367

Note: Degree of reliability = VAR(True invention quality)/VAR(Proxy invention quality). Attorney firm quality and Invention quality are standardized. Regressors include Local inventor dummy, PCT filing dummy, External attorney dummy, and technology fixed effect. (Bootstrapped standard errors)

To further assess the robustness of the relative importance of PAF quality and invention quality at the USPTO (as presented in Table 4), we re-estimated our regression using an alternative measure of invention quality. We constructed this measure using a model that regresses the number forward citations received for patent applications that were granted on a large set of patent quality indicators available at the time of application. We then use this model to predict forward citations, for both granted and refused patent applications.[24] As can be seen from Table 6 below, the results from re-estimating equation (3) using this alternative proxy are entirely consistent with our main results in Table 4.

Table 6: OLS estimates for USPTO (comparable to the OLS results in Table 4)

	Invention Quality Proxy	
	Fixed effects from other offices	**Predicted forward citations**
PAF quality	0.058***	0.036***
	(0.002)	(0.001)
Invention quality	0.007***	0.009***
	(0.001)	(0.002)
N-applications	40,367	40,090

Note: Sample size differs due to the fact that some patents do not have full set of the corresponding quality measures. PAF quality and Invention quality are standardised. Regressors include Local inventor dummy, PCT filing dummy, External attorney dummy, and technology fixed effect. (Bootstrapped standard errors)

Our analysis also rests on the use of 'grant rates' as an overall proxy for quality, which is cause for additional robustness checks. We acknowledge that the grant rate is a rough proxy for overall quality, but it is important to note that the grant rate in the USPTO in the binary logit sample is only 77.5 percent. This figure is much lower than what we would obtain on the full sample as we exclude applications that have the same examination outcome in all offices. Therefore, we believe that it provides sufficient statistical variation in examination outcome to test for the effect of PAF quality.

Nevertheless, the validity of grant as a proxy for a successful outcome is worth investigating further. Regarding the breadth and quality of the claims of the granted patents, if we only consider the English language patent applications filed at the USPTO and the EPO, we find a negative correlation between our measure of PAF quality and the number of words added to the first claim after the patent application is granted (results available on request). It is acknowledged among the patent profession that the addition of more words during the prosecution process narrows the scope of the claims (Kuhn and Thompson 2019). In addition,

[24] Concretely, we start by collecting eleven quality indicators that are available at the time of application, as well as the number of citations attracted up to ten years after the filing date. We then estimate a linear regression model on granted patents. Our regression model combines the 11 indicators and their squares as well as CPC technology classes and interaction terms between the CPC classes and the quality indicators (to allow for technology-specific effects of the patent quality indicators as suggested in Higham *et al.* 2020). We then predict the expected number of citations using the eleven quality indicators and CPC classes, which are available for all patents in the sample. Thus, we are able to obtain a predicted measure of citations for patents that were not granted.

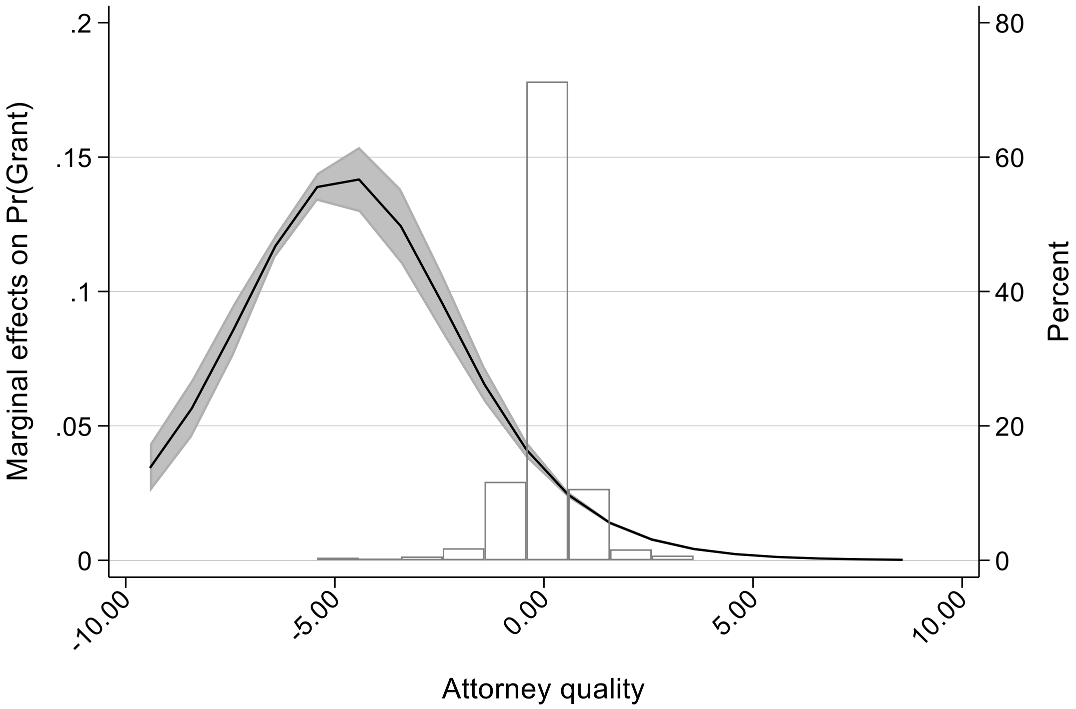
regressing the number of words added on our normalised measure at the USPTO, we find that a one-standard deviation increase in our measure of PAF quality is associated with approximately five fewer words added to the granted first claim (the average number of added words is 40). Thus, PAF quality does appear to play a more significant role at the USPTO than the EPO as our main analysis reveals. Furthermore, our PAF quality measure seems to be consistent with the intuitive idea that a 'better' attorney can get a broader patent scope.

Extensions

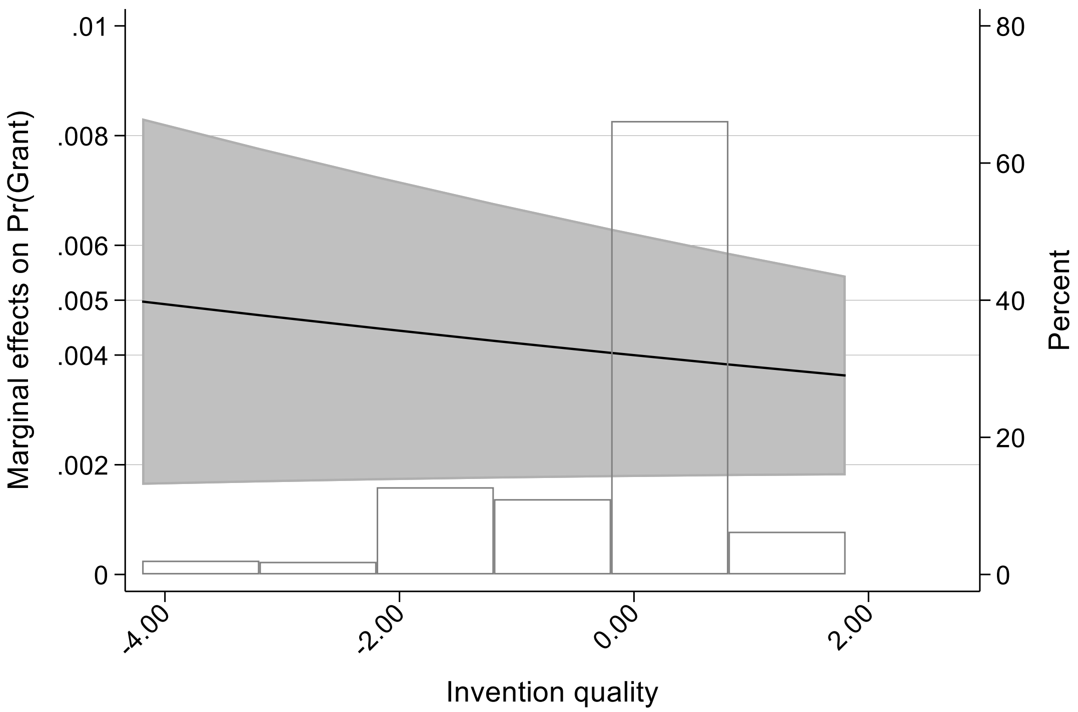
Figure 1 provides a detailed analysis of the marginal effects for PAF and invention quality at the USPTO. As can be seen from the scale on the y-axis, using a higher quality PAF at the USPTO has a greater impact on the probability of grant than having a higher quality invention, particularly for applications at the bottom of the invention quality distribution. Note that 99 percent of PAF quality observations falls between -3 and 3, hence the suggestion that themarginal effect of PAF quality is greater for better quality PAF, has very weak support.

Figure 1. Marginal effect of PAF quality (A) and invention quality (B) on the probability of grant at the USPTO, priority years 2000–2006

Panel A. Marginal effect of PAF quality



Panel B. Marginal effect of invention quality



Note: Shaded area is the 95 percent confidence interval. Standard errors are bootstrapped.
Source: Simulations based on estimated logit model for USPTO data in Table 3.

Finally, Table 7 shows how the marginal effects of PAF quality and invention quality vary across six technology groupings. It only presents the interacted terms and does not present the complete model. These estimates suggest that PAF quality is more critical for inventions in new/less mature technology areas such as ICT and Software and less critical in highly codified areas such as Chemical/Pharmaceutical and Electrical[25]

Table 7. Confounders of the effect of *PAF quality* and *invention quality* at the USPTO, priority years 2000–2006

Confounders	***× PAF quality***		***× Invention quality***	
	Logit	**OLS (Applicant FE)**	**Logit**	**OLS (Applicant FE)**
Local inventor	-0.022***	-0.060***	0.002	0.007**
	(0.002)	(0.006)	(0.003)	(0.003)
PCT filing	0.031***	0.047***	0.010***	0.005
	(0.004)	(0.008)	(0.004)	(0.005)
Electrical	-0.006	0.000	-0.002	-0.002
	(0.004)	(0.008)	(0.003)	(0.003)
Instruments	-0.034***	-0.017**	-0.005***	-0.003
	(0.007)	(0.008)	(0.002)	(0.003)
Chemical/Pharmaceutical	-0.005	0.008	0.000	0.010
	(0.013)	(0.010)	(0.004)	(0.007)
Biotechnology	0.014	0.015	-0.008	-0.015
	(0.021)	(0.009)	(0.020)	(0.027)
ICT	0.018***	0.018**	0.002	0.003
	(0.004)	(0.009)	(0.003)	(0.003)
Software	0.029***	0.018	0.006	0.003
	(0.009)	(0.013)	(0.006)	(0.007)
N	40,367	39,852	40,367	39,852

Note: () = bootstrap standard errors. ***/**/* statistically significant at 1/5/10 per cent respectively. Regression estimates are based on separate regression of each interacted technology class and PAF quality; all regressions include the regressors in the baseline non-interacted models. Dependent variable: Grant = 1 if granted; 0 if refused.

6. CONCLUSION

A rich body of theoretical work has derived the conditions under which the patent system promotes innovation. Patents should encourage businesses to invest in the creation and commercialization of ideas, especially when the creators need to sell them to third parties. However, the system's effectiveness in attaining that goal rests on the assumption that optimal patentability criteria are implemented appropriately in patent law and appropriately executed by patent offices. This paper documents an important source of potential distortion

[25] We do not believe the size of the coefficients are sensitive to the sub-sample sizes. For example, even a 5.8% share of software patent in the USPTO sample equates to a sample size of more than 2000. Further, the share of software patent is the second lowest, yet it is statistically significant.

in the patent examination process, namely the influence of PAFs, which may lead low-quality (*i.e.,* obvious or not socially-valuable) inventions to be granted and/or high-quality inventions to be refused a patent.

Note that the existence of a positive 'patent attorney firm effect' is not prima facie evidence of deadweight loss. For instance, if patent applications that pass the bar (and, hence, should be granted) are systematically associated with a high-quality PAFs whereas patent applications that do not pass the bar (and, hence, should be refused) are systematically associated with low-quality PAFs, the attorney firm effect we observe might even be welfare improving. Although a positive correlation between PAF quality and invention quality is possible, this is not present in our dataset (the correlation is -0.05).

In order to examine the welfare loss issue further, we consider whether higher quality PAFs can significantly raise the probability of a patent grant after conditioning on invention quality. Importantly, we do observe that the effect of PAFs is larger for low-quality inventions, and that this effect is even larger if the application is in a technology field that is less codified, such as ICT or software. Furthermore, at the USPTO, we find that the effect of PAF quality is actually larger than the effect of invention quality. This result is consistent with Tabakovic and Wollmann (2018) who find that patent examiners grant significantly more patents to the firms that later hire them.

Scholars and policy analysts should not assume that high-quality inventions will be granted a patent—or, conversely, that low-quality inventions will be refused a patent. Previous literature has shown that distortions exist in the examination process, mainly through the random allocation of patent applications to patent examiners with different stringency levels—and that this effect has real-world consequences (Sampat and Williams 2019, Farre-Mensa *et al*. 2020). We add to this literature by showing that the choice of PAF has a sizeable effect on the probability of grant.

Patent laws stipulate that a patent application should be assessed on the technical merit of the invention, not on the patent attorney's arguments. However, the reality is that the patent prosecution process is complex to navigate, and our results suggest that PAFs' ability matters to a surprisingly large extent. The distortion that we observe has potentially harmful welfare consequences because firms with deep pockets are more likely to select high-quality PAFs (assuming there is a correlation between PAF fees and quality) to prosecute their patent applications. In that sense, the patent system may help maintain the uneven playing field rather than levelling it.

Although our results are limited to the patent examination process, the benefits of high-quality PAFs are likely to extend well beyond that. Indeed, the description of the claimed invention in the granted patent document matters in court proceedings, should the validity of the patent be challenged in a court of law. In this respect, high-quality PAFs are presumably also more likely to write patent claims that will stand up if tested in a court of law. Alternatively, if unwarranted patents are more likely to end up in litigation, this can be more socially wasteful than a more stringent patent examination system. Without information on the deleterious effects of low-quality patents in force, we cannot quantify the effects on the economy.

Finally, we have treated PAFs as a black box, but a logical extension of the present work would investigate factors behind PAF quality. Because PAFs are a collection of individual patent practitioners, 'quality' could come from organization-level routines or individual-level skills—and presumably a combination of both. Understanding why PAFs differ in quality is beyond the scope of this article, and we hope that future research will tackle this question.

APPENDICES

A – Dataset Construction

The construction of the dataset involved complex data extraction and linking from distinct sources. The main data source is PATSTAT, which provides information on priority filings and their equivalent(s); inventor/applicant country of residence; technological fields (use of International Patent Classification codes); and filing route (PCT/Paris Convention). We used the OECD Harmonised Applicant Names (HAN) database for PATSTAT to improve on the identification of applicants within jurisdictions.[26]

The application status in each of the five offices were collected from the EPO's INPADOC PRS table for PATSTAT, JPO's public access on-line Industrial Property Digital Library Database, KIPO's public access on-line IPR Information Service, and USPTO Public Pair on-line database.

Attorney information was collected from Espacenet; the USPTO Bulk Downloads of Patent Application Information Retrieval (PAIR) Data; the Japanese Platform for Patent Information and the Japan Patent Attorneys Association; the Korean Intellectual Property Rights Information Service on-line search platform; and the Chinese on-line patent search tool, Patent Search and Analysis of CNIPA and the All-China Patent Attorneys Association (ACPAA).[27] The patent attorney information from the JPO, the KIPO and the CNIPA was largely clean—accordingly this information was harmonised using a simple string match. EPO patent attorney information was collected from Espacenet with additional information extracted from patent applications provided directly by the EPO. USPTO and EPO PAFs were identified and harmonised using a bigram matching as per the procedure used in Julius and de Rassenfosse (2014).[28] We selected the PAF and not the individual attorney because applications can be jointly produced by several individuals within a workplace. For 19.6

[26] Ninety-two per cent of applications had only one applicant. Where there was more than one applicant per family, we selected the applicant with the most applications in our dataset. The rationale is that these companies would be the most sophisticated in filing patent applications and would therefore be the most likely to take the lead.

[27] These sources are available at the following URLs: https://worldwide.espacenet.com/, https://www.google.com/googlebooks/uspto-patents-pair.html, https://www.j-platpat.inpit.go.jp, http://www.jpaa.or.jp/, http://eng.kipris.or.kr/, http://www.pss-system.gov.cn/sipopublicsearch/portal/uiIndex.shtml, http://www.acpaa.cn/

[28] http://melbourneinstitute.unimelb.edu.au/downloads/working_paper_series/wp2014n15.pdf

percent of applications to the JPO this was not possible, and the attorney identifier represented the individual rather than the attorney firm (see Appendix B for details).

To identify whether a patent attorney was in-house or not, we estimated the number of applicants each attorney had represented in our dataset. If an attorney had had only one client, we deemed it an in-house attorney (this was 2.8% of our sample). As such, this approximation will overstate the number of in-house attorneys.

The total population of applications that had one-to-one equivalents in at least two of the IP5 offices (priority years 2000–2006) was 1,264,735 applications which related to 461,961 invention families. All these applications had been examined.[29]

About 240,000 have equivalents in two of the five offices, whereas approximately 24,000 families have equivalents in all offices. As expected, these equivalent patents do not all have identical patent examination outcome across the IP5 offices. About 17 per cent of families filed and examined only in two offices were refused in both offices, 50 per cent were granted in both offices and 33 per cent were granted in one office and refused in the other. The percentage of families with mixed grant outcome jumps to 59 for 'quintuplet' families. The estimating sample for the fixed-effect binary logit estimation will differ from that for the fixed-effect linear regression model. The conditional likelihood estimation of the model requires heterogeneity in the grant decision. In other words, the fixed effect would fully explain the grant outcome if all the patent applications in the family are either rejected or granted. Of those invention families with an examination outcome (either refused or granted), 41.1 per cent have a mixed outcome.

B - Method for identifying the patent attorney firm

The percentage of applications with a non-blank address field in the EPO, USPTO, JPO, KIPO and CNIPA were 88.3, 84.9, 95.4, 99.6 and 90.5 respectively. In the EPO, USPTO and KIPO the entity name was identified from this address field. In KIPO address variables, the firm (office) is always in parentheses at the end of the variable. For CNIPA, 2 applications had missing

[29] We exclude applications that are pending or have no recorded outcome. Lazaridis and van Pottelsberghe (2007) have argued that applications to the EPO that were withdrawn after an 'X' or 'Y' citation should be regarded as 'quasi-refusals' as they were probably withdrawn in response to the negative feedback from the examiner. In our presented estimating model, we classify these EPO quasi-refusals as refusals.

attorney firm fields, and for these two applications, the attorney ID tracks the name of the individual attorney. The remainder had complete (and clean) attorney firm names.

Information for JPO applications is less complete. There are 862 individual attorneys with no attorney firm affiliation (compared with 2972 attorneys with an attorney firm affiliation). For these 862 individual attorneys, the attorney ID tracks the name of the individual attorney. This means 19.6 per cent of applications has an attorney ID rather than an attorney firm.

In all cases, the Latin names of the attorney firms were harmonised using a bigram match as per the procedure used in Julius and de Rassenfosse (2014).[30] A business executive, fluent in Japanese and Chinese, Ms Helen Szaday, reviewed the method of firm name identification. Attorney firm names were first grouped using a similarity score based on the name of the firm and its address. Subsequently, all Latin based names were manually inspected for typos, words run together, part of the address in firm name, firm names with and without generic endings (such as patent office, Rechtsanwaltskanzlei, Mbb, Patentanwaltspartnerschaft, Patentabteilung, Partnerschaftsgesellschaft, octrooibureau); names and addresses entered in wrong field; attorney firm name and inventor firm in same line. We combined the same attorney firm across offices.

We cannot easily and systematically identify patents that are transferred from one firm to another in the data (or, more generally, changes in PAF over the patent application lifecycle). The 2014 version of PAIR being the earliest available, we cannot track changes in correspondence address during the prosecution process. To understand the extent to which such changes occur, we sampled 100 patent applications and went manually over the 3000+ correspondence addresses we could find in all the published documents available in the Public PAIR portal associated to these applications. Out of the sample of 100, we observed:

- Five changes in PAF during prosecution (with presumably a change in the lead attorney in charge of the case);
- One change in PAF during prosecution following a move of the lead attorney in charge (*i.e.*, the attorneys took the case with her);

- Two changes from an external PAF to the internal IP department of the applicant during prosecution; and
- One change from a foreign attorney firm to a partner U.S. attorney firm at the beginning of the prosecution.
- One merger of the PAF during prosecution but the lead attorney remained in charge of the case in the new entity.

Considering all these cases, we concluded that about 90 percent of patent applications are prosecuted by a single attorney firm.

REFERENCES

Abowd, J.M., Kramarz, F., and Margolis, D.N. (1999). "High wage workers and high wage firms", *Econometrica* 67(2), 251–333.

Anson, W. (2018) *IP Valuation for the Future: Trends, Techniques, and Case Studies*, ABA Book Publishing

Arrow, K.J. (1962). "Economic Welfare and the Allocation of Resources for Inventions." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Edited by R.R. Nelson. Princeton, NJ: Princeton University Press.

Arundel, A. and Kabla, I., (1998). "What percentage of innovations are patented? Empirical estimates for European firms." *Research policy*, *27*(2), pp.127–141.

Bena, J., Ferreira, M.A., Matos, P. and Pires, P. (2017). "Are foreign investors locusts? The long-term effects of foreign institutional ownership", *Journal of Financial Economics*, 126(1), 122–146.

Bessen, J. and Meurer, M. (2008). *Patent Failure: How Judges, Bureaucrats and Lawyers put Innovators at Risk*, Princeton, NJ: Princeton University Press.

Bessen, J.E., 2003. "Patent thickets: Strategic patenting of complex technologies." Available at SSRN 327760.

Card, D., Heining, J. and Kline, P. (2013), "Workplace Heterogeneity and the Rise of West German Wage Inequality", *Quarterly Journal of Economics*, 128(3), 967–1015.

Chamberlain, G. (1982), "Multivariate Regression Models for Panel Data", *Journal of Econometrics*, 18, 5–46.

Chen, C., Chen, Y., Hsu, P.-H., and Podolski, E.J. (2016). "Be nice to your innovators: Employee treatment and corporate innovation performance", *Journal of Corporate Finance*, 39, 78–98.

Cockburn, I.M., Kortum, S. and Stern, S. (2002). "Are all Patent Examiners Equal? The Impact of Examiner Characteristics". *NBER Working Paper 8980*.

Cohen, W., Nelson, R.R., Walsh, J., (1996). "Appropriability conditions and why firms patent and why they do not in the American manufacturing sector". Paper presented to the Conference on New S and T Indicators for the Knowledge Based Economy, OECD, Paris, June 19–21.

de Rassenfosse, G. and E. Raiteri. forthcoming. "Technology protectionism and the patent system: Strategic technologies in china." *Journal of Industrial Economics*, in press.

Eckert, A. and Langinier, C. (2014). "A survey of the economics of patent systems and procedures", *Journal of Economic Surveys,* 28(5), 996–1015.

Elzinga, A. and Gasperini, B. (2015). "Correlated Random Effects Model: an Application to the Exchangeability of Siblings and Twins", Working Paper.

Farre-Mensa, J., Hegde, D. and Ljungqvist, A. (2020). "What is a patent worth? Evidence from the US patent 'lottery'", *The Journal of Finance,* 75 (2), 639–682.

Frakes, M.D. and Wasserman, M.F. (2017). "Is the Time Allocated to Review Patent Applications Inducing Examiners to Grant Invalid Patents? Evidence from Microlevel Application Data", *Review of Economics and Statistics* 99(3), 550–563.

Glazier, S. (2010). *Patent Strategies for Business*, 3rd Edition. LBI Law & Business Institute, Washington, D.C., 420p.

Griffith, R., Miller, H., and O'Connell, M. (2014). "Ownership of intellectual property and corporate taxation", *Journal of Public Economics*, 112, 12–23.

Griliches, Z. (1990). "Patent statistics as economic indicators: a survey", *Journal of Economic Literature*, 28, 1661–1707.

Guimaraes, P. and Portugal, P. (2010). "A simple feasible procedure to fit models with high-dimensional fixed effects", *The Stata Journal*, 10(4), 628–49.

Hall, B.H., Thoma, G., and Torrisi, S. (2007). "The market value of patents and R&D: evidence from European firms", *Academy of Management Proceedings*, 2007(1), 1–6.

Hall, B.H., von Graevenitz, G., and Helmers, C. (2021). "Technology entry in the presence of patent thickets", *Oxford Economic Papers*, 73(2), 903–926.

Harhoff, D. and Wagner, S. (2009). "The duration of patent examination at the European Patent Office", *Management Science* 55, 1969–84.

Haskel, J. and Westlake, S., 2018. *Capitalism without capital: The rise of the intangible economy*. Princeton University Press, Princeton, New Jersey.

Higham, K., de Rassenfosse, G., and Jaffe, A. B. (2021). "Patent quality: Towards a systematic framework for analysis and measurement", *Research Policy* 50(4), 104215.

Jaffe, A.B. and Lerner, J., 2007. *Innovation and its Discontents*. Princeton, NJ: Princeton University Press.

Kim, Y.K. and Oh, J.B. (2017). "Examination workloads, grant decision bias and examination quality of patent office", *Research Policy* 46, 1005–1019.

Kovács, B. (2017). "Too hot to reject: The effect of weather variations on the patent examination process at the United States Patent and Trademark Office", *Research Policy* 46, 1824–1835.

Krishnan, C.N.V, Solomon, S.D., and Thomas, R.S. (2016). "Who are the top law firms? Assessing the value of plaintiff's law firms in merger litigation", *American Law and Economics Review*, 18(1), 122–154.

Krishnan, C.N.V., Solomon, S.D., and Thomas, R.S. (2017). "The impact on shareholder value of top defense counsel in mergers and acquisitions litigation", *Journal of Corporate Finance*, 45, 480–495.

Kuhn, J. and Thompson, N. (2019) "How to Measure and Draw Causal Inferences with Patent Scope," *International Journal of the Economics of Business*, 26(1) 5–38.

Langinier, C. and Marcoul, P. (2016). "The search for prior art and the revelation of information by patent applicants", *Review of Industrial Organization* 49, 399–427.

Lemley, M.A. and Sampat, B.A. (2012). "Examiner characteristics and patent office outcomes", *Review of Economics and Statistics* 94(3), 817–827.

Lerner, J. (1994) “The Importance of Patent Scope: An Empirical Analysis,” RAND Journal of Economics, 25(2) 319-333.

Lu, Q., Myers, A.F. and Beliveau, S. (2017). “USPTO Patent Prosecution Research Data: Unlocking Office Action Traits (November 20, 2017)”, USPTO Economic Working Paper No. 2017-10. Available at SSRN: https://ssrn.com/abstract=3024621.

Merges, R. (1999) “As Many as Six Impossible Patent before Breakfast: Property Rights for Business Concepts and Patent System Reform”, *Berkeley Technology Law Journal*, 14, 577.

Mundlak, Y. (1978) “On the Pooling of Time Series and Cross Section Data”, *Econometrica*, 46, 69–85.

Nicholas, T. (2008). “Does innovation cause stock market runups? Evidence from the Great Crash”, *American Economic Review*, 98(4), 1370–1396.

Nordhaus, W.D. (1969). *Invention, growth and welfare: A theoretical treatment of technological change*. Cambridge, MA: MIT Press.

Palangkaraya, A., Jensen, P.H. and Webster, E. (2008). “Applicant behavior in patent examination request lags”, *Economics Letters* 101, 243–245.

Reiffenstein, T. (2009). “Specialization, centralization, and the distribution of patent intermediaries in the USA and Japan”, *Regional Studies* 43(4), 571–588.

Reitzig, M. (2004). “Improving patent valuations for management purposes—validating new indicators by analyzing application rationales”. *Research Policy* 33 (6–7), 939–957.

Righi, C. and Simcoe, T. (2019). “Patent examiner specialization”, *Research Policy* 48, 137–148.

Rubinfeld, D.L. and Maness, R., 2005. The strategic use of patents: Implications for antitrust. Antitrust, Patents and Copyright: EU and US Perspectives, 85, p.90.

Sampat, B. and Williams, H.L. (2019). “How do patents affect follow-on innovation? Evidence from the human genome”, *American Economic Review* 109(1), 203–236.

Sampat, B.A. and Lemley, M.A. (2010). “Examining Patent Examination”, *Stanford Technology Law Review* 2.

Schankerman, M.A. and Schuett, F. (2017). “Screening for Patent Quality: Examination, Fees and the Courts”. Available at SSRN: https://ssrn.com/abstract=2884071

Scotchmer, S. (2004). *Innovation and Incentives*. MIT Press.

Shapiro, C., (2004). “Patent system reform: economic analysis and critique”. *Berkeley Tech. Law Journal*, 19, p.1017.

Simeth, M. and Cincera, M. (2016). “Corporate science, innovation, and firm value”, *Management Science*, 62(7), 1970–1981.

Somaya, D., Williamson, I.O., and Zhang, X. (2007). “Combining patent law expertise with R&D for patenting performance”, *Organization Science* 18(6), 922–937.

Süzeroglu-Melchiors, S., Gassmann, O. and Palmie, M. (2017). “Friend or foe? The effects of patent attorney use on filing strategy vis-a-vis the effects of firm experience”, *Management Decision* 55(6), 1122–1142.

Tabakovic, H. and Wollmann, T.G. (2018). “From revolving doors to regulatory capture? Evidence from patent examiners”, NBER Working Paper No. 24638.

von Graevenitz, G., Wagner, S. and Harhoff, D., (2013). “Incidence and growth of patent thickets: The impact of technological opportunities and complexity.” *The Journal of Industrial Economics*, 61(3), 521–563.

Webster, E., Jensen, P.H. and Palangkaraya, A. (2014). “Patent examination outcomes and the national treatment principle”, *RAND Journal of Economics* 45(2), 449–69.

Westbrock, B., Muehlfeld, K. and Weitzel, U. (2019). “Selecting legal advisors in M&As: organizational learning and the role of multiplicity of mental modes”, *Journal of Management*, 45(5), 2193–2224.

Wooldridge, J.M. (2010). *Econometric Analysis of Cross Section and Panel Data*, 2nd ed. Cambridge, MA: MIT Press.

Wooldridge, J.M. (2019). “Correlated Random Effects Models with Unbalanced Panels”, Journal of Econometrics, 211, 137–150.

Younge, K.A. and Kuhn, J.M., (2016). Patent-to-patent similarity: A vector space model. Available at SSRN 2709238.