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Are patent fees effective at weeding out low-quality patents?

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Abstract

The paper investigates whether patent fees are an effective mechanism to deter the filing of low-quality patent applications. The study analyzes the effect of the Patent Law Amendment Act of 1982, which resulted in a fivefold increase in patenting costs at the U.S. Patent and Trademark Office (USPTO), on various indicators of patent quality. Using a series of difference-in-differences regressions, I find evidence that the increase in fees was associated with an increase in patent quality. The effect is strongest for companies with a small patent portfolio. The study has strong policy implications in the current context of concerns about declines in patent quality and the financial vulnerability of the USPTO.

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Keywords: intellectual property policy, patent fees, patent quality, patent reform, screening

JEL Classification: K2, O31, O34, O38

1 Introduction

Patent systems have been designed to foster innovative effort and play a central role in innovation policy. Patents provide temporary exclusion rights, which raise the private incentives to invest in research and development (R&D), thereby bringing private investment in R&D closer to the socially optimal level. Welfare is improved because the increased supply of inventions outweighs the temporary monopoly cost of patent protection. An additional benefit of patents is the disclosure of inventions, which contributes to the diffusion of ideas and encourages technological progress.

However, concerns are being raised in the United States about a ‘broken patent system’. Many observers believe that the quality of patents issued has dramatically declined since the mid-1980s, in the sense that it has become easier to obtain patents for obvious inventions or inventions that are not novel (see, for example, Barton, 2000; Hall et al., 2004; Jaffe and Lerner, 2004; Bessen and Meurer, 2008). Over the past three decades, the U.S. patent system went through a series of major changes, both legislative and via legal precedent, and it is widely held that these changes have contributed to the decline in patent quality. A significant legislative change was the establishment in 1982 of the Court of Appeals for the Federal Circuit (CAFC), which became the sole U.S. appeals court in patent cases. Quillen (2006) argues that the CAFC has lowered the standards for patentability by making it easier to obtain a patent on an obvious invention (see also Dreyfuss, 1989). Patentable subject matter was also considerably expanded through a series of court decisions. In particular, the *Diamond v. Diehr* case of 1981 allowed the patenting of computer software-related inventions, and the *State Street Bank v. Signature Financial Group* case of 1998 allowed the patenting of business methods. In the absence of access to prior art related to newly patentable subject matter, patent examiners cannot evaluate the novelty of inventions, leading to the issuance of ‘obvious’ patents (Merges, 1999).

The decline in patent quality is a cause for concern for at least three reasons. First, from a welfare perspective, patents covering obvious inventions or inventions that were already known represent a net cost to society. This is because both the incentive effect of these patents and the value of the information disclosed are nil. Although the idea of unduly handing out legal monopolies is worrying in its own right, a mistakenly granted patent may cause little harm to society if the patent is blatantly invalid, such that the threat to go to court to enforce it is not credible. However, Lemley and Shapiro (2005) point out that patents are seldom (in)valid with certainty. This creates a deadweight loss (partly because of higher market prices) and distorts ex-ante incentives to engage in research, as shown by

Farrell and Shapiro (2008). Bessen and Meurer (2008, p. 145) argue along these lines that the patent system has turned from a source of net subsidy to R&D to a net tax. Second, as patents become easier to obtain, the patenting of marginal inventions increases, leading to a fragmentation of intellectual property (IP) rights. Fragmentation significantly raises the cost of access to and use of knowledge and may ultimately lower R&D investment. This point was made by Heller and Eisenberg (1998), who report that the proliferation of fragmented and overlapping IP rights in biomedical research deters innovation. This statement is particularly true when innovation is cumulative, as it is in complex technology industries, as demonstrated by Hunt (2006) and Bessen and Maskin (2009). Third, the decrease in patent quality also presents operational challenges to the U.S. Patent and Trademark Office (USPTO). Under the current funding model, the initial processing and review of a patent application are highly subsidized by renewal fees.¹ Since low-quality patent applications must be examined but are less likely to be renewed, the increase in processing costs is not compensated by an increase in renewal revenues. The USPTO's financial vulnerability is among its top management challenges.² Although concerns about a decline in patent quality are acute at the USPTO, the issue is very much a global one. The main patent offices around the world acknowledge the importance of delivering high-quality patents and are committed to improving quality standards.³

Several policy actions have been adopted with a view to fixing the patent system, such as increasing the rigor of patent examination, allowing post-grant opposition, and implementing so-called patent prosecution highway agreements that establish the mutual recognition of search and examination work among patent offices. An additional possible policy action would be to use patent fees to self-screen patent quality. Theoretical works have shown that patent fees can be used to screen patent quality, but there is no empirical validation of this claim.

The objective of this paper is to investigate whether patent fees act as an effective ex-ante screening of patent quality. Similarly to Lanjouw and Schankerman (2004), I use the term 'quality' to emphasize both the technological and economic value of patents. That is, this paper asks whether patent fees can be used to reduce the filing of patent applications describing inventions of low technological and economic significance. This research question

¹A. Rai, S. Graham and M. Doms, 'Patent Reform: Unleashing Innovation, Promoting Economic Growth & Producing High-Paying Jobs'. White paper from the U.S. Department of Commerce, April 13, 2010.

²See 'USPTO Performance and Accountability Report: Fiscal Year 2010', and 'USPTO 2010–2015 Strategic Plan'.

³See, for example, the statements about quality in the 'Four Office Statistics Report 2010 Edition', October 2011, JPO, Tokyo, 82p.

fits into the broad literature on the optimal design of patent systems (see, for example, DeBrock, 1985; Matutes et al., 1996; Gallini, 2002; Farrell and Shapiro, 2008), and more particularly on the use of fees as a policy tool (see, for example, Scotchmer, 1999; Gans et al., 2004; Caillaud and Duchêne, 2011). It is a particularly propitious moment to study the patent fee policy. The Leahy-Smith America Invents Act, recently signed into law, has given more flexibility to the USPTO to set its fees.

To answer the research question, I exploit a quasi-natural experiment which occurred in the United States in 1982. To address the declining financial situation of the USPTO in an era of increasingly tight budgets for federal agencies, Congress passed the Patent Law Amendment Act (PLAA), which resulted in a fivefold increase in overall patenting costs. I estimate a series of difference-in-differences regressions using five measures of patent quality as dependent variables: the number of citations received by the patent; the size of the patent family; the number of years the patent remained valid; and the originality and generality scores of the patent. The treatment group is composed of priority patent applications by U.S. firms, while the control group is composed of second filings by foreign firms. Treatments and controls are matched on pre-reform characteristics of firms' patent portfolio to increase homogeneity between groups.

To anticipate the results, I find evidence of a significant increase in patent quality after the reform. The result is robust to a range of alternative specifications. Estimates of the increase in average patent-quality indicators caused by the reform range from 1 per cent to 14 per cent depending on the quality indicator used and the model specifications adopted. Estimates based on a composite quality indicator suggest an average quality increase of 3 to 4 per cent. However, I find that the fee elasticity of quality decreases with the size of the patent portfolio, suggesting that the use of fees to screen quality is more effective on patentees with a modest patent budget. Finally, I also find that screening intensity decreases almost linearly with patent quality. Although the fee increase mostly affected low-quality patents, it also prevented some high-quality patents from being filed.

The rest of the paper is organized as follows. Section 2 provides background information on patent quality, the use of fees to screen quality, and the reform. Section 3 explains the empirical strategy. The data are presented in section 4 and the econometric results in section 5. The last section offers policy implications.

2 Background

Patent quality

The concept of patent quality is difficult to pin down. Three broad definitions are possible. A first definition, common in the economic literature, relates to the quality of the underlying invention, and is measured by its technological merit and economic potential (Lanjouw and Schankerman, 2004). This definition echoes the patentability criteria assessed by patent examiners. Indeed, an invention must be sufficiently novel, non-obvious (technological merit), and useful (economic potential) in order to be patentable.⁴ In this context, a low-quality patent application is one that has no technological merit (has a low inventive step) or is not useful. A second definition, predominant among legal scholars, relates to the quality of the underlying *patent right*. A low-quality patent is one that would not have been granted if the legal requirements of novelty, non-obviousness, and usefulness had been properly evaluated (Merges, 1999). By extension, the term low quality is used to designate patents that are not clearly valid (what Farrell and Shapiro, 2008 call ‘weak’ patents). A third definition is operational and relates to the quality of the *drafting style* of the patent document. Low-quality patent documents make excessive and broad claims and use an imprecise language.

A key distinction between the definitions of quality relates to the reference quality threshold. While the economic definition implies an *optimal threshold* against which patent quality is evaluated (*e.g.*, Denicolò, 2008), the legal and operational definitions assess patent quality against the *actual threshold* of the patent office. Clearly, the current concerns about patent quality are related to both aspects: the patent office’s quality threshold, the inventive step, is believed to be too low (see Barton, 2000, among others) and the examination process has been shown to be imperfect, leading to patents being mistakenly granted (*e.g.*, Merges, 1999; Palangkaraya et al., 2011). In fact, these two aspects are intimately linked. As patents become easier to obtain, more patent applications are filed, which reduces examination quality as examiners are put under pressure to maintain reasonable pendency delays. This further increases the chance of having a low-quality patent application granted, leading to an increased supply of such patent applications (Jaffe and Lerner, 2004; Caillaud and Duchêne, 2011; van Pottelsberghe, 2011).

This paper studies whether patent fees can act as an effective ex-ante screening of patent

⁴The concept of ‘usefulness’ in patent law is only weakly related to the economic potential. An invention is ‘useful’ if it provides some identifiable benefit and is capable of use (Bedford v. Hunt, 3 F. Cas. 37 (C.C. Mass. 1817)).

applications. It is clear that patent fees have no direct effect on the quality of the underlying intellectual property right, but would rather affect the incentives to protect a low-quality invention with a patent. Consistent with this approach, I adopt the first definition of patent quality.

Patent fees to screen quality

Scotchmer (1999) and Cornelli and Schankerman (1999) were the first to propose that fees could be used to screen patent quality. For instance, Cornelli and Schankerman (1999) show that renewal fees can be used to implement a policy of optimally differentiated patent lives that increases social welfare compared to a uniform patent life (see also Baudry and Dumont, 2006, for recent work on renewal fees). Caillaud and Duchêne (2011) explicitly look at patent filing fees in the context of congested patent offices with imperfect examination. They show that there exists a range of values of application fees which lead to a unique high-R&D equilibrium in which firms self-select in their decision to apply for a patent. Picard and van Pottelsberghe (2011) study how the mode of governance of patent offices affects the setting of fees and the quality of the examination process. In their model, the willingness to pay the fees increases with the inventiveness of the patent.

To the best of my knowledge, there has been no empirical validation of the relationship between fees and quality. Empirical studies on patent fees have focused mainly on estimating the price elasticity of demand for patents (see de Rassenfosse and van Pottelsberghe, 2012a, for a recent survey of the literature on patent fees). Estimates performed on patent filing fees typically vary around -0.3, meaning that a ten per cent increase in fees results in a three per cent decrease in the number of patent applications (de Rassenfosse and van Pottelsberghe, 2012b).

Since the demand for patents is sensitive to fees, it is reasonable to assume that the low end of the patent quality spectrum is likely to be most affected by a change in application fees. The closest related analysis is Nicholas (2011), who studies the effect of the 1883 Patents, Design and Trade Marks Act in Britain on the level of innovation. Nicholas finds that the dramatic lowering of patent filing fees in Britain did not affect the ‘level of innovation’, as measured by the number of citations to English inventor patents in the United States. Although insightful in many respects, the analysis is silent on how the change in fees affected the quality of patents filed at the British Patent Office, where the reform took place.

Skeptics typically advance two reasons why filing fees would have only a limited impact

on patent quality. First, a commonly heard argument is that patent fees represent only a fraction of patenting cost, which also includes attorney fees. Recent estimates for the United States put the average attorney fees at between US\$10,000 and US\$20,000 in 2007, depending on the complexity of the technology.⁵ Thus, attorney fees are far more expensive than application fees, which currently amount to US\$3,030 for the filing, search, examination, and issue of a patent application. In addition, patenting costs are usually modest in comparison with R&D costs, such that they would only marginally affect the decision to apply for a patent. This argument suggests that a change in fees must be sufficiently large to have observable effects. Second, companies imperfectly observe the quality of their inventions at the time of filing because patents are usually filed early in the life of projects.⁶ In a seminal article, Griliches (1990, p. 1,699) discusses precisely this issue. He argues that under perfect information about invention quality, a rise in the cost of patenting would deter the marginal, low-quality inventions. At the other extreme, too large a degree of uncertainty at the time of filing would limit the effectiveness of patent fees as a screening device. Griliches' opinion is explicit: 'The truth, I believe, is somewhere in the middle, but closer to the first case, with some definite knowledge about the potential importance of the particular invention.' Allison et al. (2004) provide empirical evidence that patent holders are able to identify valuable patents at the time of application. From a mechanism design point of view, however, what matters is not so much how well firms observe quality, but whether they have more information about quality than the patent office has.

This paper provides a direct test of the effect of application fees on patent quality. It analyzes how the PLAA affected various indicators of patent quality.

The U.S. Patent Law Amendment Act of 1982

Implementation of the PLAA, which resulted in a drastic increase in patent fees, provides an ideal policy-change framework for studying the effect of fees on patent quality. It led to the largest increase in fees in the history of the USPTO (de Rassenfosse and van Pottelsberghe, 2012a) and it occurred sufficiently long ago for patent quality indicators to be available without truncation. It was also implemented for reasons that are not related to concerns about quality. At that time, indeed, patent quality at the USPTO was not an issue.

The PLAA was largely adopted to strengthen the financial resources of the USPTO

⁵American Intellectual Property Law Association, 'Report of the Economic Survey 2007', 2007, p. 78–81.

⁶For instance, Kondo (1999) analyzes the dynamic mechanism of the R&D-patent relationship of Japanese industry and shows that R&D expenditure leads to patent applications with a 1.5 year time-lag. Pakes (1986) estimates an option model of patents and finds evidence of a learning effect early in patent life.

in an era of increasingly tight budgets for federal agencies. According to a 1980 House Report (H.R. 96-1307), patent fees had not been adjusted since 1967.⁷ At that time, the fee structure provided revenue which met 67 per cent of the costs of operating the USPTO. By 1980 inflation had reduced the real value of patent fees, which were estimated to cover a mere 27 per cent of the operating costs. The fee increase became effective on October 1, 1982 (Public Law 97-247).

Patenting cost increased fivefold as a direct consequence of the reform. Official fees from filing to grant rose from an estimated US\$239 before the reform (H.R. 96-1307) to US\$800 after the reform. In addition, the reform also introduced renewal fees, which are due 3.5, 7.5, and 11.5 years from the date of the original patent grant. Renewal fees increase linearly with age, from US\$400 in year 3.5 to US\$1,200 in year 11.5. Thus the fees for maintaining a patent to full term rose from US\$239 to US\$3,200. Available data suggest that official fees accounted for a high share of total patenting costs borne by applicants, such that the reform substantially raised overall patenting costs. Based on a survey of patent attorneys, Helfgott (1993) reported that patent attorney fees in the United States averaged around US\$635 in 1992. Assuming that attorney fees followed the evolution of the consumer price index (CPI) would give a 1983 figure of US\$440. This would imply that the reform raised overall patenting cost from US\$679 to US\$3,640.

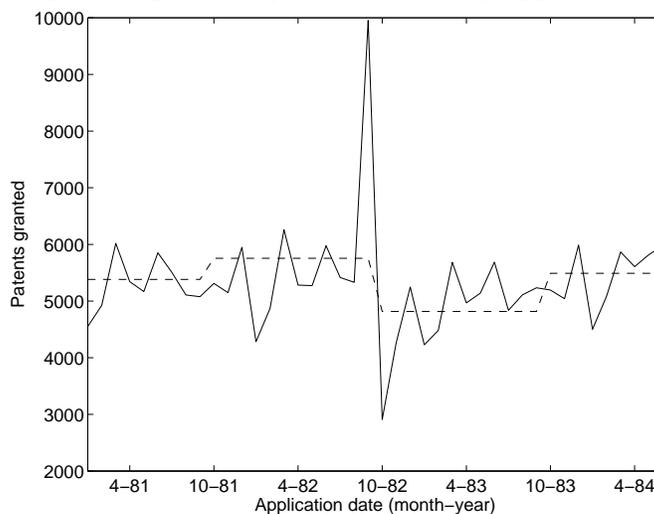
Figure 1 shows the monthly evolution of USPTO patents granted, by application date. The effect of the reform is clearly visible, with a peak in patenting in September 1982, immediately followed by a drop in October. This suggests that applicants rushed to file their patent applications before the fee increase, providing a first sign that fees matter. The quality of patents filed immediately around the time of the reform will be formally studied in section 4.3, but results suggest that the average quality was significantly higher for patents filed in October than for those filed in September. The reform also seems to have had a lasting effect on the demand for patents. The total number of patent applications fell from 116,052 in 1982 to 96,847 in 1983 and 109,010 in 1984. At the same time, total funds for industrial R&D grew by 9 per cent annually, from US\$93,496 million in 1982 to US\$110,553 million in 1984 (in constant 2000 dollar terms).⁸

The long-term effect of the reform on patent quality is more difficult to estimate. A

⁷See also G. Griswold, 'Testimony on FY 1999 Appropriations for the Patent and Trademark Office', April 1, 1998.

⁸See 'USPTO Annual Report FY 1993', Table 6: Patent applications filed (FY 1973–1993); National Science Foundation's '2005 Survey of Industry Research and Development', Table 2: Industrial Research and Development performed in the United States, by source of funds (1953–2005).

Figure 1: Number of patents granted by the USPTO, by application month (1981–1984).



Notes: Number of patents granted by the USPTO. The dashed line represents the monthly average over the fiscal year.

Sources: Patstat April 2011. Own computation.

potential approach would involve studying the evolution of the grant rate. At constant examination quality, an increase in the grant rate would suggest an increase in the quality of patent applications. Unfortunately, the USPTO provides unit records for granted patents only and does not publish details for patent applications that were rejected. It is thus not possible to estimate precisely how the grant rate evolved after the reform. Nevertheless, one can obtain a rough approximation of the grant rate using data aggregated directly by the USPTO. I observe in my data that patents filed in 1982 were granted on average two years and four months after the filing date, while patents filed in 1983 were granted after two years and three months. The total number of utility patent applications was 116,052 in 1982 and 96,847 in 1983, while the number of patents issued two years later was 66,753 and 69,667 respectively.⁹ Hence, the grant rate was approximately 57 per cent for patents filed in 1982, and 72 per cent for patents filed in 1983 (it was 51 per cent in 1981 and 65 per cent in 1984). Assuming no change in the examination process, these figures would suggest that patent applications filed after the fee increase were of higher quality than those filed before.¹⁰ This approach is very crude, however. Next section presents the empirical

⁹See ‘USPTO Annual Report FY 1993’, Table 9: Patents issued (FY 1974–1993).

¹⁰There is no indication of a change in the examination process after the reform. Both patent pendency and the number of patent applications per examiner remained stable. There were slightly less than 90

framework adopted to assess the effect of the increase in fees on patent quality.

3 Empirical approach

I observe only granted patents. By definition, granted patents went successfully through examiners' screening, so that any increase in quality observed after the reform may result from an actual strengthening of examination rigor, rather than from an increased supply of high-quality patents. However, the legislative reports accompanying Public Law 97-247 did not mention the possibility of increased rigor in the examination process, and no concerns were voiced about low-quality patents. Contemporary issues of patent quality were not a concern in the early 1980s. The sole stated purpose of the PLAA was to strengthen the financial resources of the USPTO. In addition, the grant rates computed in the previous section and the figures discussed in footnote 10 suggest that examination rigor did not increase.

Nevertheless, a careful econometric analysis is needed to identify the causal effect of fees on quality. The cornerstone of the empirical strategy is to exploit variations in patenting cost both within and between groups of individuals (*i.e.*, variations over time and across groups) using a difference-in-differences (DID) regression model. By identifying distinct groups of applicants, the DID approach controls for potential confounding factors such as changes in examination rigor: even if examination rigor changed after the reform, it is unlikely that it also changed between groups. The next section explains the approach in detail.

3.1 Exploiting a difference in cost between priority filings and second filings

The DID strategy exploits a variation in relative patenting cost between two groups of patents: patents by U.S. applicants, which are mainly *priority filings*, and patents by foreign applicants, which are mainly *second filings*. A priority filing is the first patent application protecting an invention. It is generally filed in the company's home country. When a priority patent application is subsequently filed in another jurisdiction, with the

patent applications per examiner in 1982 and 1983, and slightly more than 90 in 1984 and 1985 (Source: R. Katznelson, 'My 2010 Wishes for the U.S. Patent Examiner'. January 2010, Figure 3. Available at: <http://works.bepress.com/rkatznelson/60>.) Note that the grant rates obtained are only crude approximations, as emphasized by Quillen et al. (2002).

aim of extending the patent protection to a foreign market, the patent document is called a second filing.

Inventions protected with second filings are valuable enough to warrant international protection and are thus of higher quality on average than inventions described in priority filings only. This fact is well established in the empirical literature (for example, Lanjouw et al., 1998; Chan, 2010) and is explained by the fact that a high cost has been borne for second filings. The overall patenting cost of a second filing includes official and attorney fees in both the home and the foreign country and may also include translation fees, so that it is much higher than the cost of a priority filing.

Identification comes from a different sensitivity to patenting fees between groups. Because second filings at the USPTO form a highly selected group of patents, I expect them to be less sensitive than priority filings to an increase in fees. Accordingly, the regression model compares the quality of USPTO patents by U.S. companies (treatment group of priority filings) to the quality of USPTO patents by foreign companies (control group of second filings). Because second filings are overwhelmingly owned by large companies, the sample is limited to patents by large U.S. and foreign companies.¹¹ This selection increases homogeneity between groups. Next, pre-reform patents by firms that did not obtain at least one patent in the post-reform period were excluded. This restriction ensures that observations in the pre-reform period have at least one counterpart in the post-reform period. To further increase homogeneity (and ensure common support) between treatments and controls, a 1-to-1 exact matching is performed on pre-reform characteristics of the patent portfolio. Details of the matching are provided in section 4.

The equation to be estimated is:

$$Q_{it} = \gamma + \delta_w \cdot post_t + \delta_b \cdot local_i + \delta_{DID} \cdot (post \times local)_{it} + \beta X_i + \varepsilon_{it} \quad (1)$$

where Q_{it} is a measure of the quality of patent i filed at time t ($t = 0$ before the reform and $t = 1$ after the reform), $post_t$ is a dummy variable that takes the value t , $local$ is a dummy variable that takes the value 1 if the patent document is a priority patent granted to a U.S. company and 0 if the patent document is a second filing granted to a foreign company, and X_i is a matrix that controls for the main technology class of the patent as well as for time effects. The variable $post \times local$ is the average treatment effect. It is an interaction variable that captures the extent to which the quality of patents by U.S. companies changed

¹¹Thus, the sample also excludes university-owned patents, thereby mitigating the potential effect of the Bayh-Dole Act. The Bayh-Dole Act, enacted on December 1980, allows universities to retain ownership to inventions made in the course of federally funded research.

as a result of the fee increase relative to the change in the quality of patents by foreign companies. If patent quality is sensitive to fees, the quality of patents by local companies should have increased vis-à-vis the quality of patents by foreign companies, such that I expect δ_{DID} to be positive. Because the unit of analysis (a patent) is more detailed than the level of variation in fees, the errors may be correlated within groups (U.S. vs. foreign patents). In order to account for a common group effect, standard errors are clustered at the group level. The regression is estimated using ordinary least squares (OLS), although alternative estimation methods will be tested.

3.2 Patent quality indicators

As explained in section 2, the quality of a patent is defined by its technological merit and its economic potential. It is assessed using five indicators: the number of citations received by the patent (Q_C); the size of the patent family (Q_F); the active life of the patent (Q_L); and the originality (Q_O) and generality (Q_G) scores of the patent.

The *number of citations* received by a patent has been shown to be a good measure of its technological importance (*e.g.*, Carpenter et al., 1981; Narin et al., 1987; Albert et al., 1991) as well as its economic value (Trajtenberg, 1990). For instance, Albert et al. (1991) study a sample of 77 USPTO patents granted to Eastman Kodak in 1982 and 1983 and find that patent citations correlated well with experts' opinions on the technological importance of patents. Other authors have also used citation data to estimate the probability that a patent should be granted (Palangkaraya et al., 2011). However, recent criticisms have been made regarding the use of patent citations, especially because many citations are added by examiners and not by applicants themselves (see, for example, Alcácer and Gittelman, 2006, on the measurement of knowledge flows). As far as patent quality is concerned, recent results by Hegde and Sampat (2009) actually suggest that examiner citations increase the informational content of citation counts. They find that examiner citations are strong predictors of patent value.

The *family size* is the number of jurisdictions in which patent protection is sought. It was first used by Putnam (1996) and Lanjouw et al. (1998). The rationale is that inventions protected by a large international family are of high value given the many costs incurred in the international patent application process. Using data from a survey of patent holders in Germany, Harhoff et al. (2003) report that patents representing large international families correlate particularly well with estimates of patent values. Chan (2010) takes a detailed look at the international patenting decision of nine agricultural biotechnology firms in the

1990s. The author finds that invention quality plays an important role in firms' decisions to patent abroad.

Patent life is also a useful indicator of patent quality. Most patent offices require the regular payment of renewal fees in order to keep the patent in force. The use of patent renewal data rests on the premise that inventions for which patent protection is more valuable will tend to be protected by payment of renewal fees for longer periods (Schankerman and Pakes, 1986). MacLeod et al. (2003) emphasize that the use of renewal data is valid as long as inventors do not face credit constraints that would prevent otherwise valuable patents from being renewed. Although renewal fees are usually due every year, providing a fine-grained measure of value, renewal fees at the USPTO are due 3.5, 7.5, and 11.5 years from the date of the original patent grant. As explained in section 2, renewal fees were introduced with the reform. However, interestingly, the law had a retroactive effect in the sense that renewal fees had to be paid for all the patents applied for on or after December 12, 1980.

Originality and *Generality* scores are citation-based measures of patent quality that have been proposed by Trajtenberg et al. (1997). The originality score captures the dispersion of cited technologies made by the patent. A patent that cites previous patents that belong to a narrow (broad) set of technologies will have a low (high) originality score. The generality score is similar, except that it relates to citing technologies: A patent that is cited by subsequent patents that belong to a narrow (wide) range of technology fields will have a low (high) generality score. Patent quality is often assumed to be positively correlated with originality and generality scores although, to the best of my knowledge, there has been no validation study of these variables.

4 Data

I combine data from three sources. The central database is the April 2011 edition of Patstat, the worldwide patent statistical database by the European Patent Office (EPO). It provides a listing of patents granted by the USPTO as well information on the technology classes of patents, the number of citations (Q_C), and the family size (Q_F). The second database is the USPTO Patent Maintenance Fee Events database, which is used to compute the active life of patents (Q_L). The third database is NBER Patent Citations Data (Hall et al., 2001). It provides the originality (Q_O) and generality (Q_G) scores of patents. Section 4.1 explains details of the construction of the dataset, and section 4.2 explains how the various quality indicators were computed.

4.1 Dataset

The first step of the dataset construction involves identifying all patents filed at the USPTO around the time of the reform. I include all patents filed 21 months before and after the reform, that is, from January 1, 1981 to June 30, 1984, using Patstat.¹² The choice of the start date is motivated by the fact that January 1981 is the first month for which all the patent-quality indicators can be constructed. There are 223,329 such patent documents. These patent documents all correspond to *granted patents*, because the USPTO at that time did not publish patent applications that were rejected. Among these patents, 350 patents could not be matched with the USPTO Patent Maintenance Fee Events database and 144 patents had no International Patent Classification (IPC) code. IPC codes are assigned by examiners and indicate the technological area to which the invention belongs. I use the two-digit level classification and select the main IPC code listed in the patent document.¹³ There are also an additional 29,108 patents with no originality and generality scores. The database thus contains a total of 193,727 USPTO patents with complete information.

The next step in the data construction involves selecting all patents by large companies (150,215) and splitting the sample into priority filings by U.S. firms and second filings by foreign firms. There are 66,660 priority filings, and 59,986 of them were filed by U.S. firms. There are 83,555 second filings, and 50,837 of them were filed by foreign firms.¹⁴ The former group of patents constitutes the basis for the treatment group, while the latter group constitutes the basis for the control group.

As explained in section 3.1, I remove all the pre-reform patents by firms that did not file patents after the reform. There are 6,532 such patents in the treatment group and 6,133 in the control group. The matching is performed on the remaining 53,454 patents in the treatment group and the remaining 44,704 patents in the control group. More specifically, I compute three key firm-level variables based on observable pre-reform characteristics of the patent portfolio: the size of the patent portfolio in the pre-reform period, the industry in which the firm obtained the largest number of patents, and a measure of the dispersion

¹²Concretely, I: (i) selected all the patents filed at the USPTO available in Patstat (259,838); (ii) excluded 1,913 patents such as plant patents and design patents; (iii) excluded 27,962 ‘dummy’ patents created for technical reasons in Patstat; and (iv) excluded 6,498 PCT patents for which the USPTO is the receiving office. See de Rassenfosse et al. (2012) for methodological details.

¹³A patent document can contain more than one IPC code. Because IPC codes are aggregated at the two-digit level (so that ‘C04B 2/02’ becomes ‘C04’), a patent may list several times the same aggregate IPC codes. In such cases, the main IPC code is the most frequent one. Otherwise, the main IPC code is simply the first code listed in the patent document. There are 120 two-digit codes.

¹⁴I took the precaution of excluding patents with U.S. and foreign co-assignees.

of the patent portfolio across industries (Herfindahl index of industry dispersion). I am able to match patents from 1,882 firms, accounting for 11,573 pre-reform patents from the treatment group; 9,118 post-reform patents from the treatment group; 11,354 pre-reform patents from the control group; and 10,614 post-reform patents from the control group. These figures provide an important insight into the sensitivity to fees of controls and treatments. The number of patents in the treatment group dropped by 21.21 per cent, while the number of patents in the control group dropped by only 6.52 per cent, thereby confirming the intuition that patents in the control group are less sensitive to fees than patents in the treatment group.

4.2 Construction of patent quality indicators

The number of citations received by a patent (Q_C) is computed by counting the number of times the patent document was cited ten years after grant. I consider only citations of USPTO patents; I exclude citations of patents filed in other jurisdictions. The citation count is subject to an inflation bias because the number of citing patents increases with the growing number of patent applications. This issue will be dealt with in the econometric analysis through the inclusion of time dummies.

The size of the patent family (Q_F) is computed by counting the number of jurisdictions covered by the patent documents in the same INPADOC family. The INPADOC family encompasses all the patent documents that are linked directly or indirectly through a priority document. I also construct a variable that controls for the number of USPTO patents in the same family (variable *NumLocFamMembers*) to avoid artificially inflating the family size. For instance, it can be the case that three priority patents granted by the USPTO (patents A, B, and C) are later merged together in one second filing at a foreign office (patent D). In such a situation, the invention is protected in two jurisdictions (the United States and the foreign country, $Q_F = 2$) and the variable *NumLocFamMembers* = 3 for patents A, B, and C.

The patent life (Q_L) is computed from the USPTO Patent Maintenance Fee Events database. Every patent that has expired is associated with a code 'EPX.' and a corresponding expiration date in the database. Patents that are not associated with an expiration code were maintained to full term.

The originality (Q_O) and generality (Q_G) scores are directly available from the NBER Patent Citations Data file by Hall et al. (2001).

4.3 Descriptive statistics

A significant increase in quality immediately after the reform would provide some prima facie evidence that fees affect quality. Table 1 shows the average values of the five quality indicators for patents filed by U.S. companies in September and October 1982. The quality indicators systematically increased after the reform. The average number of citations received in a ten-year time window was 5.67 for patents filed in September 1982 and 6.05 for patents filed in October 1982 (+ 6.70 per cent). The average family size went from 2.04 before the reform to 2.52 after the reform, which means that priority patents filed before (after) the reform were extended in one country (1.5 countries) on average (+ 23.53 per cent). Patents filed immediately before the reform remained valid for an average period of 11.78 years, whereas patents filed directly after the reform had approximately a one-year increase in their life expectancy (+ 9.17 per cent). Finally, the originality score increased from 0.34 to 0.36 (+ 5.88 per cent) while the generality score increased from 0.37 to 0.38 (+ 2.70 per cent). These increases are in all cases always significantly greater than zero, as indicated in the last column of Table 1, which reports the one-tailed p-value for the t-test that the difference in means between October and September values is equal to zero (the alternative hypothesis is that October values are greater than September values). For the sake of comparison, Table 1 also reports the average values of quality indicators for patents filed one year earlier. The null hypothesis that average values from October are not significantly different from average values in September cannot be rejected. This result implies that there is no systematic seasonal fluctuation in the value indicators. Table 1 provides some tentative evidence that patent fees may be effective at filtering out low-quality patents.

However, the sharp increase observed might simply be evidence of a short run intertemporal substitution.¹⁵ The next section provides a detailed econometric analysis of the long-run effect of fees on patent quality.

¹⁵An alternative explanation for the difference in quality between patents filed in September and those filed in October would be that companies rushed to file patents for inventions that were not fully developed, hence of lower quality. Note that the argument that the reform would signal increased rigor in examination cannot explain the difference in quality indicators in the short term, since patents filed immediately before the reform would arguably be examined with the same rigor as those filed immediately after.

Table 1: Average value of quality indicators, around the reform and one year before.

Around the reform (N = 5,805)			
	September 1982	October 1982	Oct \neq Sep
\bar{Q}_C	5.67	6.05	0.06
\bar{Q}_F	2.04	2.52	0.00
\bar{Q}_L	11.78	12.86	0.00
\bar{Q}_O	0.34	0.36	0.00
\bar{Q}_G	0.37	0.38	0.09
One year before the reform (N = 4,600)			
	September 1981	October 1981	Oct \neq Sep
\bar{Q}_C	5.53	5.60	0.38
\bar{Q}_F	2.34	2.20	0.95
\bar{Q}_L	12.50	12.19	0.95
\bar{Q}_O	0.34	0.34	0.78
\bar{Q}_G	0.37	0.37	0.33

Notes: ' \bar{x} ' indicates mean value of ' x '. The variable Q_F is divided by *NumLocFamMembers*. See section 4.2 for variable definitions. The last column reports the p-value for the t-test that the difference in mean between October and September values is equal to zero.

5 Econometric results

5.1 Baseline results

Table 2 presents estimates of the DID equation (1), which compares the quality of USPTO patents between U.S. and foreign large companies. The time window used for the regression encompasses the patents filed up to 21 months before and after the reform, and excludes 2,334 patents filed in September and October 1982. The exclusion of patents filed in September and October is motivated by the peak in patent applications depicted in Figure 1, which suggests that patenting activity was strongly disrupted around the reform. The time window purposefully excludes the disruption period to avoid a potential contamination of the data. Thus, the results presented are net of any transitory effects.

Equation (1) is estimated with the number of forward citations (Q_C), the family size (Q_F), the patent life (Q_L), the originality score (Q_O), and the generality score (Q_G) as dependent variables in columns (1)–(5) of Table 2. The regression model used in Panel A is OLS, while the regression models used in Panel B take the particular nature of the depen-

dent variables into account. The citation count and family size equations were estimated with a negative binomial regression model (count data); the life equation was estimated with an ordered probit regression model (after transforming the variable Q_L into a 1 to 4 ordinal variable, where 1 means ‘never renewed’ and 4 means ‘renewed to full term’); and the originality and generality scores were estimated with a quasi-maximum likelihood (QML) estimator proposed by Papke and Wooldridge (1996) for proportion data.

Patents by U.S. companies attract more citations, have a smaller family size, live longer, and are more original and general than patents by foreign companies as seen from the coefficients associated with the variable *local*. The average treatment effects (coefficients associated with the interaction term *post* \times *local*) are all positive and (almost) always significant, in both Panels A and B. These results suggest that the quality of patents by U.S. companies increased relative to their foreign counterparts after the reform. Figures for the OLS model (Panel A) suggest that patents filed by large U.S. companies received an additional 0.51 citations, had a family size larger by 0.62 members, lived 0.03 years longer (not significantly different from zero) and increased their originality and generality scores by 0.02 and 0.03 respectively. These figures correspond to increases in the average value of quality indicators of 3 per cent, 14 per cent, 2 per cent, 1 per cent, and 1 per cent respectively. Effects estimated with the alternative estimation methods (Panel B) are in a similar range.

Patent quality is inherently difficult to capture, and it is a remarkable result that all the patent-quality indicators increased after the reform. In the next table, equation (1) is estimated with a composite quality measure (Q^*) as dependent variable, corresponding to the score on the first axis of a factor analysis of the five quality indicators. A baseline OLS estimate is presented in column (1), while the estimates in columns (2) and (3) control for the skewed distribution of the dependent variable. More than half of the patents received four or fewer citations, while some patents received more than 200 citations, and about half the patents were not extended abroad. An OLS estimate with the dependent variable taken to the logarithm is presented in column (2), and a quantile regression, which measures the effect on the median, is presented in column (3). These approaches confirm the findings and suggest a mean quality increase of about 3 per cent and a median quality increase of about 4 per cent.

The average treatment effect estimated in the above tables can hide important disparities across firms. In particular, I suspect that the intensity of the response functions varies with the size of the patent portfolio held by firms. To test this hypothesis, I estimate the DID regression model on four subsamples constructed according to the number of patents

Table 2: Estimation of equation (1) on matched samples, baseline results.

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Q_C	Q_F	Q_L	Q_O	Q_G
PANEL A					
Estimation method:	OLS	OLS	OLS	OLS	OLS
<i>post</i>	0.234 (0.174)	-0.166 (0.118)	-0.170 (0.049)	0.003 (0.002)	0.005 (0.002)
<i>local</i>	1.162** (0.062)	-2.603*** (0.021)	0.687* (0.072)	0.047* (0.004)	0.033* (0.003)
<i>post</i> \times <i>local</i>	0.509** (0.008)	0.624*** (0.004)	0.033 (0.008)	0.006*** (0.000)	0.007*** (0.000)
R ²	0.080	0.166	0.027	0.049	0.064
PANEL B					
Estimation method:	Neg. Bin.	Neg. Bin.	O. Probit	QML	QML
<i>post</i>	0.056** (0.025)	-0.035 (0.035)	-0.038*** (0.012)	0.015 (0.011)	0.023*** (0.006)
<i>local</i>	0.167*** (0.016)	-0.577*** (0.020)	0.122*** (0.012)	0.214*** (0.018)	0.143*** (0.012)
<i>post</i> \times <i>local</i>	0.044*** (0.000)	0.141*** (0.003)	0.013*** (0.002)	0.025*** (0.000)	0.028*** (0.000)
R ²	0.076	0.163	0.025	0.049	0.064

Notes: 42,659 observations were used. Constant term, industry dummies, and year dummies included but not reported. The regressions for Q_F include a control for the number of USPTO patents in the family (variable *NumLocFamMembers*). Standard errors clustered at the group level are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 per cent probability threshold respectively. The R² in Panel B is computed as the square of the correlation coefficient between the predicted and the actual values. The time window is 01/1981–08/1982 and 11/1982–06/1984.

held by firms in the pre-reform period: patents by firms that had between 2 and 5 patents in the pre-reform period (6,462 observations); patents by firms with 6 to 20 patents (8,915 observations); patents by firms with 21 to 100 patents (11,354 observations); and patents by firms with a portfolio size greater than 100 patents (9,984 observations). The results are illustrated in Figure 2.

The upper panel of Figure 2 presents the unit increase in quality for the composite indicator. These figures directly correspond to the parameter associated with the DID coefficient in equation (1) and can be directly compared with the DID coefficient in column (1) of Table 3. The panel shows that the effect on quality decreases with the size of the patent portfolio, implying that the fee elasticity of quality decreases with portfolio size. However, it is difficult to interpret these figures directly because the average quality of patents in the pre-reform period may also vary with portfolio size. The lower panel of Figure 2 presents the effect on quality in percentage terms. The increase in quality is approximately 10 per cent for firms that obtained between 2 and 5 patents in the pre-reform period, 6 per cent for firms that obtained between 6 and 20 patents in the pre-reform period, 2 per cent for firms that obtained more than 20 patents in the pre-reform period. Figure 2 clearly illustrates that the increase in quality was greater for smaller patentees. The reform had no statistically significant impact on firms with a very large patent portfolio.

Lastly, I study screening intensity as a function of quality by assessing the quality range for which screening was stronger. It is not possible to answer this question directly since I do not observe patents not filed because of the fee increase. An indirect way of answering the question involves comparing the distribution of patent quality in the treatment group before and after the reform. The mean value of the quality indicator Q^* for the treatment group of priority filings by large U.S. companies is 4.197 in the post-reform period and 3.907 in the pre-reform period. In order for the mean quality to be equal across periods, I need to remove all the pre-reform patents below the threshold $Q^* = 1.64$, or approximately 10 per cent of the lowest-quality patents. Doing so, however, severely truncates the pre-reform quality distribution, which does not match well with the post-reform quality distribution. Thus, it seems that screening intensity is not a binary process that occurs only below a certain threshold but rather a continuous one.

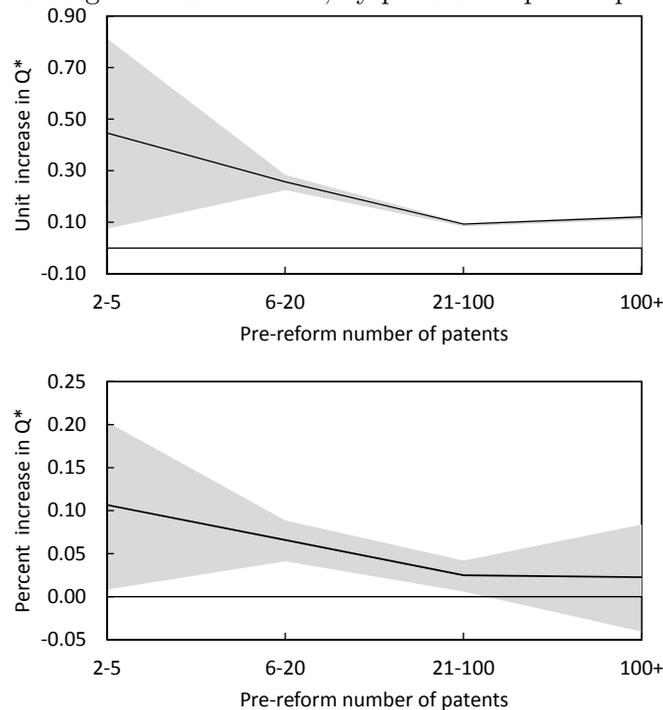
Allowing for a continuous screening that affects the whole quality range is more challenging to carry out. It involves matching pre-reform quality density with post-reform quality density. For that purpose, I first divide the post-reform density into 20 blocks of equal weight (5-percentile steps); I observe that 5 per cent of the patents are in the quality range $[0, 1.43]$, the next 5 per cent of patents are in the range $(1.43, 1.77]$, etc. Second,

Table 3: Estimation of equation (1) on matched samples, composite quality indicator.

	(1)	(2)	(3)
Dependent variable:	Q^*	$\ln Q^*$	Q^*
Method:	OLS	OLS	Quantile Reg.
<i>post</i>	0.042 (0.044)	0.010 (0.006)	0.023 (0.055)
<i>local</i>	0.368** (0.024)	0.064* (0.006)	0.195*** (0.025)
<i>post</i> \times <i>local</i>	0.163** (0.003)	0.037*** (0.000)	0.132*** (0.040)
R^2	0.083	0.078	0.034

Notes: 40,325 observations were used. Constant term, industry dummies, and year dummies were included but not reported. The time window is: 01/1981–08/1982 and 11/1982–06/1984. Standard errors clustered at the group level are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 per cent probability threshold respectively. Pseudo R^2 values are reported in column (3).

Figure 2: Average treatment effect, by pre-reform patent portfolio size.



Notes: Gray areas represent the 95 per cent confidence interval.

I remove a selected number of patents in each block of the pre-reform density, such that the filtered pre-reform quality distribution mimics the post-reform quality distribution. For instance, 6.65 per cent of the pre-reform patents were in the range $[0, 1.43]$ so that I can estimate how many patents should be removed in order for the first block of patents to account for 5 per cent of total pre-reform patents. The result of the process is depicted in Figure 3. The left-hand panel plots the various densities, while the right-hand panel shows the intensity of screening that resulted from matching the densities.

As expected, the quality distributions are highly skewed to the left, and the (unfiltered) pre-reform density (dotted line) exhibits more mass on the left than the post-reform density (black line). The pre-reform screened density is depicted in gray and shown to mimic the post-reform density. The right-hand panel shows that screening intensity decreases with patent quality. Almost 40 per cent of the patents below the 5th percentile were filtered out, whereas almost no patents above the 80th percentile needed to be filtered out. The latter panel clearly illustrates that screening is not a binary process but a gradual one: Although low-quality patents were mainly affected, a non-trivial proportion of high-quality patents was also affected. This result could be a consequence of the high uncertainty faced by patentees at the time of filing.

5.2 Validity and robustness tests

This section reports a series of validity and robustness tests aimed at gauging the stability of the results.

Parallel-trend assumption

A key assumption of DID estimates is that the average quality of patents by large U.S. companies follows the same trend in the pre-treatment period as that of patents by large foreign companies (the so-called ‘parallel-trend assumption’). It ensures that the control group provides an adequate basis for the counterfactual case. The evolution of the trends in quality indicators for treatments and controls is depicted in the left-hand panel of Figure 4. Although the level of quality indicators differs between groups, a visual check suggests that trends are similar between groups. This intuition is formally confirmed by looking at the right-hand side panel of Figure 4, which reports the 95 per cent confidence interval of the difference in trends. The changes are not significantly different from zero for each quality indicator, indicating that the trends follow a similar pattern.

Time windows

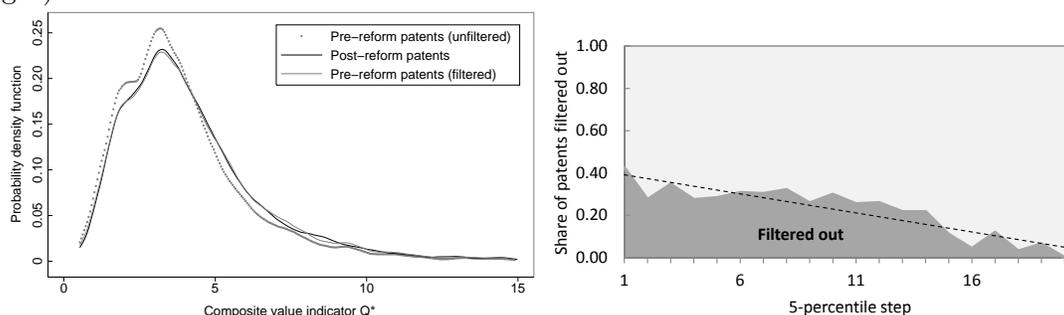
A second robustness test involves evaluating the sensitivity of the results to the time window used. I report estimates performed with the composite quality indicator as the dependent variable in the interest of space. The regression results presented in column (1) of Table 4 are estimated over a 42-month time window centered on the reform, excluding patents filed two months before and after the reform (instead of one month in the baseline case). The regression results presented in column (2) are estimated over a 42-month time window centered on the reform, including the disruption period. The estimated increases in quality are 9 and 10 per cent, respectively. Note that the regressions always include year dummies. The inclusion of year dummies makes it possible to control, among other things, for the inflation in citation rates over time. To guard against the possibility that the year dummies might interfere with the variable *post*, the year dummies were replaced by a (monthly) time trend, as presented in column (3) of Table 4. The interaction term is positive and significant, and corresponds to a 6 per cent increase in quality. The last column reports the result of a placebo test performed one year before the reform. The interaction term is not significantly different from zero, suggesting that controls and treatments did not differ before the reform. This result can also be seen as a confirmation of the parallel-trend assumption.

Other confounding factors

Finally, although the DID framework was adopted precisely to control for unobserved heterogeneity, I look more closely at identified confounding factors and how they could affect the estimates. One such factor is the establishment of the CAFC, which, in 1982, became the sole U.S. appeals court in patent case. Strong arguments allow us to discard the hypothesis that the establishment of the CAFC would affect the estimates. First, observers of the patent system believe that the CAFC led to an increase in the number of patent applications and a decrease in patent quality by lowering the standards for patentability (Hall, 2005; Quillen, 2006). Interestingly, I observe opposite effects, namely a decline in the number of patent applications and an increase in patent quality following the reform. Thus, if anything, the establishment of the CAFC would play against the results, making the estimates presented more conservative. Second, it admittedly took time for firms to note the pro-patent shift by the CAFC and to react accordingly.¹⁶ This view is supported by Bender et al. (1986), Strawbridge et al. (1987) and Hall (2005). The CAFC spent its

¹⁶In addition, other authors have also argued that the CAFC has only partially mitigated nonuniformity across circuits (Atkinson et al., 2009).

Figure 3: Superimposition of density curves (left) and corresponding screening intensity (right)



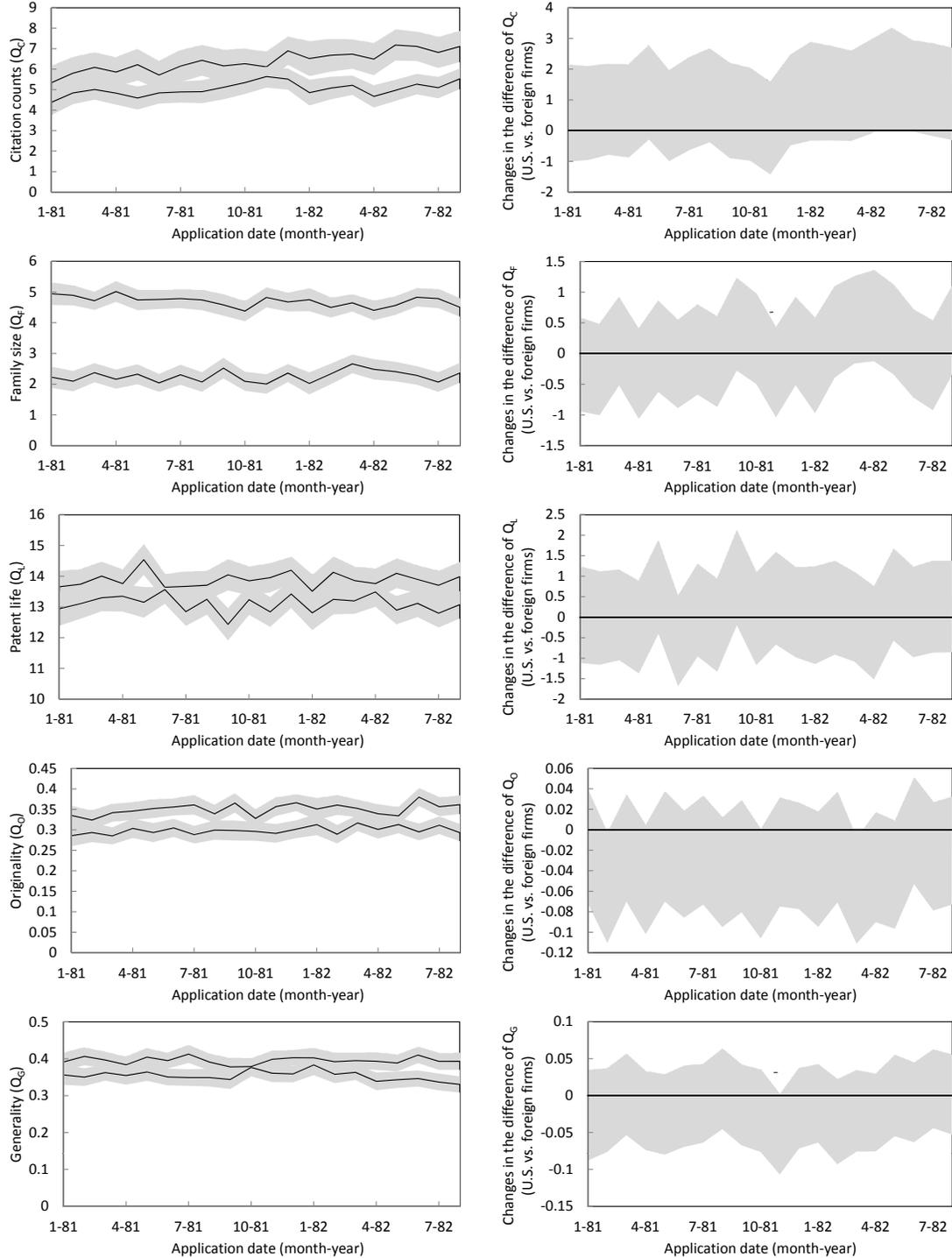
Notes: The dotted line in the right-hand panel represents the linear regression line of screening intensity ($R^2 = 0.82$).

Table 4: Estimation of equation (1) on matched samples: various time windows and time trends.

	(1)	(2)	(3)	(4)
Time window:	A	B	Baseline	Placebo
<i>post</i>	0.071 (0.058)	0.042 (0.050)	-0.117 (0.074)	-0.831 (0.772)
<i>local</i>	0.364** (0.024)	0.373** (0.024)	0.369** (0.025)	0.348** (0.009)
<i>post</i> × <i>local</i>	0.166** (0.004)	0.156*** (0.003)	0.162*** (0.002)	0.005 (0.027)
Monthly trend	-	-	0.013 (0.003)	-
R ²	0.083	0.082	0.083	0.090
Observations	38,360	42,659	40,325	18,982

Notes: The dependent variable is the composite measure of quality Q^* . Constant term, industry dummies, and year dummies were included but not reported (there are no year dummies in column (3)). Time window A: 01/1981–07/1982 and 12/1982–06/1984; B: 01/1981–06/1984; Placebo: 01/1981–06/1982. Econometric method is OLS with standard errors clustered at the group level reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 per cent probability threshold.

Figure 4: Evolution of quality indicators before the reform (U.S. vs. foreign large firms).



Notes: Figures in the left-hand panels show the evolution of quality indicators for patents by large U.S. firms and large foreign firms (the gray areas represent the 95-percent confidence intervals). Figures in the right hand panels show the 95-per cent confidence interval of changes in the difference between the two series.

first two years (1983 and 1984) solving many apparent conflicts in patent law opinions of the regional circuit courts of appeals, while it reaffirmed precedents in 1985 and 1986 (Bender et al., 1986; Strawbridge et al., 1987). Similarly, Hall (2005, p. 37) considers that the litigation successes of Texas Instruments in 1985 and 1986 and of Polaroid against Kodak in 1986 were a ‘strong motivation for increased defensive patent filings’. These events occurred well after the fee reform and are outside the time window, such that it is unlikely that the establishment of the CAFC would affect the results. Nevertheless, two robustness tests were performed to ensure the validity of the results. Equation (1) is estimated on a sample that excludes patents in the areas most affected by the CAFC and the ‘patent explosion’. The sample used in column (1) of Table 5 excludes patents in the electrical sector, broadly defined to include electric machinery, electronics, instruments, computers, and communication equipment (Hall, 2005).¹⁷ The results presented in the next column control for potential changes in the industrial composition of patenting activity. The regression in column (2) includes an interaction term between the variable *post* and each industry dummy. The interaction term $post \times local$ is always positive and significant, and represents an increase in quality following the reform of 6 per cent.

The estimate presented in column (4) of Table 5 controls for the broader macroeconomic context. The log of quarterly GDP is included into the regression to account for the effect of the economic slowdown of the early 1980s on the patenting behavior of firms. The results remain unchanged.

Effect in home country of foreign firms

The DID setting does not follow conventional textbook wisdom because both treatments and controls were subject to a policy change. Yet, this particular setting does not compromise the validity of the findings: as long as the intensity of the behavioral response to a change in fees differs between groups, this setting provides information about whether patent fees affect quality. However, it also affects the economic interpretation of the average treatment effect δ_{DID} . Since the control group was also subject to a change in fees, the variable δ_{DID} underestimates the true effect on quality. It is indeed likely that the quality of patents in the control group also increased, such that the approach presents a conservative estimate. One can get a sense of the size of the ‘bias’ by looking at the coefficients associated with the dummy variable *post* in Tables 2 and 3. The coefficients are usually

¹⁷The allocation of patents to industrial sectors was performed using the OECD concordance table, which assigns IPC codes to industries.

Table 5: Estimation of equation (1) on matched samples, controlling for industry effects.

	(1)	(2)	(3)
<i>post</i>	-0.030 (0.034)	-0.333 (0.168)	0.042 (0.043)
<i>local</i>	0.224*** (0.003)	0.396*** (0.001)	0.368** (0.024)
<i>post</i> × <i>local</i>	0.196** (0.009)	0.172** (0.005)	0.163** (0.004)
ln <i>GDP</i>	-	-	1.117 (0.423)
Industry dummies	Y	Y***	-
<i>post</i> × Industry	-	Y***	-
R^2	0.018	0.046	0.083
Observations	17,860	40,219	40,325

Notes: The dependent variable is the composite measure of quality Q^* . Patents from International Standard Industrial Classification (Rev. 3) class number 29, 30, 31 and 32 removed in column (1). Econometric method is OLS with standard errors clustered at the group level reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 per cent probability threshold (test of joint significance for industry dummies reported). Constant term and year dummies were included but not reported. Technology dummies are included in column (3).

small in magnitude compared with the average treatment effects, which is consistent with the interpretation that second filings are much less sensitive to fees. This observation is not entirely accurate since the variable *post* picks up any change in quality after the reform that was common across groups—including, possibly, an overall decrease in quality—and because year dummies also capture any transversal changes in quality that could have occurred after the reform.

An attempt to address this issue is performed in two stages. First, I estimate the DID regression model using control patents that were probably among the least sensitive to fees. I use exclusively patents by German companies as the control group of foreign patents. The group of U.S. second filings granted to German companies is a strong control group because the German patent system is usually seen as a high-quality system involving a high inventive step (see, for example, Michel and Bettels, 2001, p. 189). In addition, having been substantially changed in 1976 (Mueller and Wegner, 1977), German patent law did not undergo any major reform in the early 1980s.¹⁸ Finally, the total patenting cost for German companies willing to protect an invention in the United States is much higher than that for U.S. companies. It is composed of the filing fees at the German patent office (Deutsches Patent- und Markenamt, or DPMA) and the USPTO, the attorneys’ fees in both countries, and fees for translating the original patent document into English. In a survey of patent attorneys around the world, Helfgott (1993) estimated that the cost of translating a typical patent application from German to English was US\$2,000 in 1992, equivalent to US\$1,400 in 1983 using the CPI deflator. Thus, translation fees alone were more expensive than U.S. attorneys’ fees and application fees combined (see section 2).

Second, I also study how the quality of patents in the control group changed vis-à-vis the population of priority filings in Germany. At the limit, if the quality of second filings by foreign firms stayed constant, the parameter δ_{DID} would provide a valid estimation of the magnitude of the effect of fees on quality. The change in the quality of German second filings can be assessed with the following regression:

$$Q_{it} = \gamma + \delta_w \cdot post_t + \delta_b \cdot uspto_i + \delta_{DID} \cdot (post \times uspto)_{it} + \beta X_i + \varepsilon_{it} \quad (2)$$

where the unit of observation i is a priority patent application filed at the DPMA by a German company. The dummy variable *uspto* takes the value 1 if the priority filing was subsequently filed at the USPTO and 0 otherwise. The time window is moved one year forward (from January 1, 1980 to June 30, 1983) to take into account the twelve-month

¹⁸See also Ginarte and Park (1997) who report that the strength of patent rights in Germany changed only slightly throughout the 1980s.

priority period to which applicants are entitled. Thus, the variable *post* takes the value 1 for DPMA patents filed on or after October 1, 1981, because these patents were likely to have been transferred to the USPTO on or after October 1, 1982, when the reform came into force. The coefficient δ_{DID} in equation (2) measures the extent to which the quality of German priority filings subsequently extended at the USPTO (that is, German second filings) changed after the reform relative to the control group of all the other priority filings at the DPMA. A coefficient not significantly different from zero in equation (2), or a sufficiently small coefficient, would suggest that the control group in equation (1) provides a stable benchmark.

The data used for estimating equation (1) is similar to that described in section 4.1 except that I restrict patents in the control group to second filings by large German firms. There is a total of 11,254 such patents.¹⁹ The data used for estimating equation (2), which relates to patents filed at the DPMA, is briefly described below. The first step involves identifying all the priority patent applications filed at the DPMA by German applicants in the period from January 1, 1980 to June 30, 1984.²⁰ I identify a total of 109,595 DPMA priority filings by all German applicants during that period. I remove 123 patents for which there is no IPC code. The dataset thus contains 109,472 DPMA patents. Among these patents, there are 13,917 priority filings (direct equivalents) that were subsequently transferred at the USPTO between January 1, 1981 and June 30, 1984 (and, for the most part, filed at the DPMA between January 1, 1980 and June 30, 1983), as well as all 70,096 priority patent applications filed at the DPMA between January 1, 1980 and June 30, 1983 but not extended to the USPTO.²¹ The sample thus contains a total of 84,013 patents. The EPO Worldwide Legal Status database provides information on lapses of DPMA patents (Q_L). Since the originality and generality scores are computed for U.S. patents only, the regression will focus on the following three quality variables: Q_C , Q_F , and Q_L . The results are presented in Table 6.

Estimates of equation (1) are presented in columns (1)–(3) for the three quality variables.

¹⁹For the sake of consistency with equation (2), the DID is performed on unmatched samples. I thus capture the population-wide effect. There are 63,285 patents in the treatment group.

²⁰The period goes back to January 1, 1980 because applicants can wait up to twelve months before transferring a priority patent application to the USPTO. Hence, a priority patent application filed on January 1, 1980 at the DPMA can be transferred to the USPTO until January 1, 1981. In theory, a patent filed on June 30, 1984 at the DPMA can also be filed the same day at the USPTO.

²¹Direct equivalents are USPTO patents which claim a one-to-one priority link with German priority filings. In other words, a DPMA priority filing must be claimed by only one second filing at the USPTO, and the USPTO second filing must claim only the focal priority filing for it to be a direct equivalent.

Table 6: Estimation of equations (1) and (2) using German patents as reference.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Q_C	Q_F	Q_L	Q_C	Q_F	Q_L
Equation:	1	1	1	2	2	2
<i>post</i>	-0.356 (0.197)	-0.112 (0.076)	-0.140* (0.016)	0.003 (0.015)	-0.051** (0.010)	-0.185 (0.065)
<i>local</i>	1.387** (0.082)	-2.786*** (0.030)	2.128** (0.056)	-	-	-
<i>post</i> × <i>local</i>	0.706*** (0.007)	0.382** (0.022)	0.292** (0.015)	-	-	-
<i>uspto</i>	-	-	-	0.374** (0.058)	3.674*** (0.307)	0.844*** (0.028)
<i>post</i> × <i>uspto</i>	-	-	-	-0.024 (0.012)	0.001 (0.017)	0.000 (0.096)
R ²	0.101	0.148	0.052	0.042	0.360	0.026
Observations	74,539	74,539	74,539	79,711	79,711	32,684

Notes: Constant term, technology dummies, and year dummies were included but not reported. The regressions for Q_F include a control for the number of USPTO patents in the family in column (2) and for the number of DPMA patents in the family in columns (5) (variable *NumLocFamMembers*). Estimation method is OLS with standard errors clustered at the group level reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 per cent probability threshold.

The average treatment effects are always positive and significant, and suggest a mean quality increase of 4 per cent for the number of citations, 42 per cent for the family size, and 2 per cent for the average life. These figures are larger than those presented in Table 2, suggesting that German second filings indeed provide a more stable control group. (They were presumably less sensitive to fees than most other second filings, such that the relative increase in the quality of U.S. patents is larger when evaluated against German second filings than when evaluated against the group of all second filings.) The average quality increase for the composite quality indicator is 19 per cent (not reported), which is higher than the figure obtained using the matched sample of all second filings.²² The stability of the control group is investigated in columns (4)–(6) of Table 6, which report estimates of equation (2) for the three quality indicators. As expected, the quality of priority filings subsequently transferred to the USPTO is significantly higher than the quality of priority filings not transferred, as witnessed by the significant coefficients associated with the variable *uspto*. Interestingly, the coefficients δ_{DID} are not significantly different from zero, suggesting that the U.S. fee reform did not affect the quality of patents that German companies transferred to the USPTO. This finding implies that the control group of German second filings provides a stable benchmark against which to evaluate the increase in quality of patents by U.S. companies. It suggests at the very least that estimates provided in previous sections are conservative.

6 Concluding remarks

This paper investigates the effect of the U.S. Patent Law Amendment Act of 1982 (which involved a fivefold increase in patenting costs) on the quality of patents at the USPTO. The empirical analysis presents evidence that the increase in fees was associated with an increase in the quality of patents. Results from a matched-sample DID indicate that the net increase in the average quality of patents caused by the reform ranges from 1 per cent to 14 per cent depending on the quality indicator that is used and the econometric specifications adopted. Considering the various point estimates, the reform is likely to have induced a 3 to 4 per cent increase in patent quality. However, the increase in quality was not constant across the board and smaller patentees were more severely affected. The quality increase of patents by firms with a pre-reform patent portfolio size of fewer than 20 patents was

²²Note that the quality increase is 4 per cent when the composite indicator is constructed from Q_C , Q_F , and Q_L . The quality increase for the variables Q_O and Q_G is approximately 2 per cent and significant at the 10-per cent probability threshold.

10 per cent, whereas the quality increase for large patentees (with more than 100 patents) was about 2 per cent. Lastly, the analysis shows that the increase in patent fees also prevented high-quality patents from being filed, although screening intensity was stronger for low-quality patents.

The study comes with some limitations. First, patent quality is difficult to measure. Although special attention was devoted to building several indicators of patent quality, these indicators are noisy and imperfectly capture the ‘true’ quality. Having said this, the quality indicators all suggest that patent quality improved as a consequence of the reform, increasing our confidence in the results. Second, the empirical analysis is not guided by a behavioral model of the firm and its environment. As such, the analysis is subject to Lucas’ critique (Lucas, 1976), meaning that the results may have limited predictive power. The legal environment has changed since the early 1980s, and the increased emphasis on the alternative, strategic uses of patents has modified patenting practices. It would be erroneous to directly transpose the estimates to the current situation. However, the main message of the empirical analysis is likely to remain: that is, that a sufficiently strong increase in fees would weed out low-quality patents. Third, the paper is silent on the optimal level of fees and quality. This limitation is true for the literature in general, as economists have been cautious about giving estimates of ‘optimal’ patent fees.

The study has important implications for intellectual property policy. A fee reform, much like any tax reform, must be studied from three perspectives: revenues, efficiency, and equity. It is well established empirically that an increase in fees will increase the total revenues collected by patent offices because the price elasticity of demand for patents is inelastic. As far as the efficiency of the reform is concerned, an increase in fees will reduce the number of patent applications, which will reduce processing time, and increase the average quality of patents, thereby improving the overall functioning of the patent system. Regarding the equity dimension, the results presented in this paper show that small patentees were more severely affected by the increase in fees mandated by the 1982 legislation. In fact, the fee reform had only a limited impact on the quality of patents filed by firms with a very large patent portfolio. Thus, fee reform should come along with measures aimed at mitigating its distortionary effect, such as reduced fees for small patentees or for first-time applicants. However, further work is needed to understand the net welfare gains of an increase in fees. While the benefits are fairly obvious, the costs are more difficult to evaluate. These include the exclusion of cash-poor players, a potential reduction in the incentives to invest in research, and a higher prevalence of secrecy. In the current context of concerns about patent quality, large backlogs and financial vulnerability of patent offices,

the results suggest that it is worth giving full consideration to the patent fee policy.

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