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A comparative analysis of patent infringement awards in the US, Japan, and China

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It is logical to expect that a patent of higher value will merit higher patent infringement awards in patent litigation. Up to now, however, little empirical evidence exists to support it. We provide a comparative analysis of the correlations between patent infringement awards and three aspects of patent value among the US, Japan, and China. Furthermore, we examine two potential factors that may lead to higher patent infringement awards in the US than those in Japan. Finally, we compares the predictability of patent infringement awards ruled by US judges and that of those ruled by US juries.

1. Introduction

Patent systems have been established to stimulate innovation in many countries. However, not all of them work well. One of the preconditions for the functioning of the patent system is the effective enforcement of patent rights. Patent enforcement can be divided into formal methods of enforcement, such as patent infringement litigation, and less formal methods of enforcement, such as sending a cease and desist letter to stop an infringer's act or negotiating with the infringer to licensing the patent right. Prior literature has found that although infringement is common, patent litigation is only the tip of the enforcement iceberg and that much enforcement occurs informally (Weatherall, 2014).

Although it is only the tip of the enforcement iceberg, patent litigation plays an important role in the operation of patent systems. Outcomes of patent litigations significantly impact efficacy of less formal mechanisms of patent enforcement and, therefore, affect patentees' belief of the enforceability of patent right. If most patents fail to be enforced effectively and efficiently in patent litigation, innovators will believe that patent rights do not provide an effective protection for their technologies. They will then tend not to patent their technologies or even reduce their R&D investment and try to freeride patented technologies of third parties. In parallel, patent owners will fail to monetize their patent rights through licensing, selling, or other methods. If so, patent systems will fail to stimulate innovation. Patent litigation

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as the most formal enforcement method should therefore be designed to give innovators enough confidence that patent rights can be enforced effectively by both formal methods and informal methods.

In this study, we focus on patent infringement awards and provide a comparative empirical analysis of the correlations between the indicators of patent value and patent infringement awards among the US, Japan, and China. We also discussed two possible factors that lead to lower patent infringement awards in Japan than those in the US and compared the predictability of patent infringement award ruled by Judges and those ruled by juries. This article proceeds as follows. The following section presents some facts and a literature review on patent infringement awards. Section 3 describes the hypotheses of this study. Section 4 describes the data and variables. Section 5 presents a descriptive picture of patent infringement awards in the three countries. Section 6 presents econometric results. Section 7 provides discussion and conclusion.

2. Prior literature on patent infringement awards

Patent Acts in in the US, Japan and China provide different optional methods of calculating patent damages. The United States Patent Act provides only two optional methods: patentee's lost profits and reasonable royalty. The Japanese Patent Act provides three optional methods: patentee's lost profits, defendant's profits, and reasonable royalty. The Chinese Patent Law also provides four optional methods: patentee's lost profits, defendant's profits, reasonable royalty and statutory compensation.

Lost profits and reasonable royalty are used to calculate patent damages in all three countries. However, the difficulty of persuading the court to award lost profits is different among the three countries in practice. According to the language of Section 284 of the United States Patent Act, US courts prefer to award actual damages in the form of lost profits unless the patentee fails to prove the causation between damages and the act of infringement (Takenaka, 2000). In the US, the *Panduit* test was established by the 6th Circuit to determine "but for" causation (Frank and DeFranco, 2000). To obtain lost profits, a patentee must establish the four requirements of the Panduit "but for" test: (1) market demand for the product covered by the patented technology; (2) an absence of non-infringement substitutes to satisfy the demand in the same market; (3) the patentee's manufacturing and marketing capacity to exploit the demand; and (4) the amount of profits that the patentee would have made if infringement had not occurred (Frank and DeFranco, 2000; Love, 2009). If a patentee sells a product covered by the patent-in-suit, he can usually satisfy the requirements of the *Panduit* test and be awarded lost profits. In some cases, for example, if a patentee can recover lost profits by selling one of the existing products not covered by the patent-in-suit but adversely affected by the infringement act, he may also be entitled to a lost profit award (Frank and DeFranco, 2000). After the revision of the Japanese Patent Act in 1998, it may have become easier for a patentee to obtain lost profit awards in Japan than in the US because the new provision only requires a patentee to show two of the four *Panduit* factors used in the US and shifts the burden of proof to the defendant's party greatly (Takenaka, 2000). In the case of China, Hu (2007) argued that the courts strictly enforce standards of proof so that statutory compensation has been applied in most cases.

Furthermore, the courts in all the three countries attach significant weight to the prior royalty rate of the patent-in-suit. However, if no prior royalty exists, the three countries handle that differently. In the US, if no prior royalty rate exists, the courts attach less weight to the industry standard royalty rates and more

weight to the patent owner's licensing policy (Takenaka, 2000). Absence of prior licenses indicates that the patentee is unwilling to license the patent and tends to benefit from the exclusivity, so the courts tend to increase the royalty rate. In contrast, in Japan, if no prior royalty exists, the courts tends to refer to the industry standard royalty rates or the royalty rates of government-owned patents, which is usually lower than the royalty rate at which the patentee is willing to license. Fortunately, the 1998 revision of the Japanese Patent Act enables the courts to increase the royalty rate to a higher level than the industry standard royalty rate or the royalty rate of government-owned patents. In China, statutory compensation is applied to determine patent damages if no prior royalty rate exists.

It is well known that US patent infringement awards are significantly higher than those in most other countries. Though it is difficult to say how much is optimal, some scholars have recently argued that US patent infringement awards overcompensate patentees. Lemley and Shapiro (2007) argued that the way of calculating reasonable royalties, particularly for component inventions, results in patentees capturing more than their fair share of a defendant's profits. They suggested that calculated royalties will not be excessive if the courts consider the non-infringing alternative ways to create the infringed component and the value of the non-infringement components. In a later study, Lemley (2009) also argued that the entire market value rule should not be applied to reasonable royalty cases because there is always some value to the infringed products not attributable to the patent. Love (2009) argued that Federal Circuit is using excessive reasonable royalty awards as a deterrent and criticized that it makes no sense to do so in a patent system that already consistently overvalues patent rights. Taylor (2014) argued that a reasonable royalty should be used to value the patented technology instead of the patent rights, the value of which is usually higher than the value of the patented technology.

On the other hand, Japanese and Chinese patent infringement awards are criticized as too low to compensate the patentee's loss. Especially in China, patent infringement awards do not even reimburse the patentee's fee to bring a patent lawsuit. Takenaka (2000) argued that pre-1998 patent infringement awards in Japan were lower than those in the US mainly due to lower reasonable royalty rates and the difficulty of obtaining lost profit awards in Japan. Takenaka also argued that with the implementation of the pro-patent policy after the revision of the Japanese Patent Act, it will be easier for the patentee to get higher infringement awards or even be overcompensated. However, 10 years later, Japanese patent infringement awards are still significantly lower than those in the US. Hu (2016) argued that most commonly used method of calculating patent infringement awards in China is statutory compensation, the amount of which is generally lower than the amount claimed by the plaintiff and damages calculated by other three methods. This may to a great extent explain why patent infringement awards in China are far less than those in Japan and the US.

Patent system provides patentees imperfect protection for their patented technologies. This can be reflected in both the uncertainty of validity of a patent and the unpredictability of patent infringement awards when it is involved in patent litigation. If patent infringement awards are systematically unpredictable, the legitimacy of patent system should be reconsidered. Mazzero *et al.* (2013) studied the unpredictability of US patent infringement awards. They analyzed 340 cases decided by the US courts between 1995 and 2008 and constructed an econometric model that explains 75% of the variation in US

patent infringement awards. Therefore, they concluded that US patent infringement awards are not systematically unpredictable. In this study, we compared the predictability of patent infringement awards ruled by US judges and those ruled by juries.

3. Hypothesis

As the judges have discretionary power to determine patent damages when calculating patent damages by reasonable royalties or statutory compensation, it is reasonable to believe that they attach great weight to value of patent-in-suit subjectively. On the other hand, even if patent damages are calculated in the form of patentee's lost profits or defendant's illegal profits, a product covered by patent-in-suit of higher value will also thereby obtain higher infringement awards objectively. In this study, we examine the correlations between patent infringement awards and three aspects of patent value, economic value, technological value and breadth of utilities. A product covered by a patent of higher technological value will be sold at a higher price. A product covered by a patent of broader utilities have broader market size. A product covered by a patent of higher economic value will be sold at a higher price or/and have broader market size. Mazzero *et al.* (2013) found that US patent infringement awards are highly correlated with average number of forward citations of the patents-in-suit. Li (2015) found that Chinese statutory compensation for patent infringement are highly correlated with the scale of sale and sale price of the infringing product. Therefore, we expect:

H 1. Patents of higher economic value get higher patent infringement awards.

H 2. Patents of higher technological value get higher patent infringement awards.

H 3. Patents of broader utilities get higher patent infringement awards.

The US jury system is a special one that does not exist in Japan and China. In a patent jury trial, juries play an important role in deciding questions of fact, especially in deciding the infringement issues and the amount of damage awards (Signore, 2001). Recently, more and more patent suits are decided by juries in the US. Meanwhile, many scholars and practitioners began to be concerned that many modern patent cases are so complex that juries struggle to understand the technologies and apply the law (Wilson, 1997). Some commentators even suggest that the Seventh Amendment should be invoked to eliminate juries from patent cases in which the complexity of facts or the underlying issues are too difficult for juries to understand (Miller, 2004). Moreover, another concern is the problem of jury bias. Moore (2000, 2002) found that juries are more likely than judges to favor patent holders, the aggrieved party, and domestic parties although she does not agree that juries are incompetent to resolve patent cases. Based on this evidence, we hypothesize:

H 4. US patent infringement awards ruled by juries are less predictable than those ruled by judges.

Japanese and Chinese patent infringement awards are long been criticized significantly lower than US patent infringement awards. Hu (2016) argued that Chinese patent infringement awards are low because most of them are ruled in the form of statutory compensation which is significantly lower than damages calculated with other three methods. On the other hand, difference in patent infringement awards between the US and Japan is still puzzling. From the perspective of system design, we argue that it may lie in

some differences in law or judicial practice between the US and Japan, such as the discovery procedure, the application of entire market value rule, the jury system, and the enhanced damages system, all of which do not exist in Japan. Besides, as patent right is effective only in the country where it is granted, it may also lie in the different market sizes. Mazzero *et al.* (2013) found that patent damages awarded in jury trial are significantly higher than those awarded in bench trial. Limited by data, in this study, we only discussed whether jury system and enhanced damages system can explain the difference between the US and Japan.

H 5. Jury system leads to higher patent infringement awards in the US than in Japan.

H 6. Enhanced damage system leads to higher patent infringement awards in the US than in Japan.

4. Datasets

US patent litigation information is derived from the Westlaw database, and Japanese patent litigation information is derived from the intellectual property litigation database provided by the Supreme Court of Japan. Chinese patent litigation information is derived mainly from the Pkulaw database provided by Beijing Beidayinghua Technology Co., Ltd and partly from the website of China Supreme People's Court (http://ipr.court.gov.cn/zgrmfy/). It should be noted that patent rights are defined differently in the US, Japan, and China. In the US, patent right includes utility patents, plant patents, and design patents. In Japan, patent rights mean invention patents. In China, patent rights include invention patents, utility model patents, and design patents. As invention patents are usually more valuable than utility model patents and design patents, we focused our study on invention patent litigation in the case of Japan and China. For the US, we excluded design patent litigation and focused on utility patent litigation and plant patent litigation. All the patent information is downloaded from a commercial patent database called PatentSQUARE which is provided by Panasonic Solution Technologies Co., Ltd.. Exceptionally, number of claims for Chinese patents is manually investigated in Google Patent Search.

Based on careful reading of patent infringement lawsuit decisions in the three databases, we identified 171 award-containing cases decided by US courts between 2000 and 2012, 123 ones judged by Japanese courts between 2000 and 2014 and 508 effective ones judged by Chinese courts between 2003 and 2014. Table 1 shows the distribution of patent cases by decision year. To compare patent infringement awards decided by juries and judges, we split the dataset of US patent cases into two smaller datasets: patent infringement awards ruled by judges and those ruled by juries. To check the robustness of the regression results of Chinese patent infringement awards, we constructed a smaller dataset from which patent cases sued outside big cities including Peking, Shanghai, Guangdong, Zhejiang, and Jiangsu. Moreover, to examine if jury system and enhanced damage system in the US can explain the difference of patent infringement awards between in the US and in Japan, we constructed two additional datasets: patent infringement awards of the Japanese cases and all the US cases, and patent infringement awards of the Japanese cases and the US cases that were decided by judges and awarded no enhanced damages.

5. Variables

Patent infringement awards. Patent infringement awards are the dependent variable of interest in this study. We conducted several data-cleaning processes on patent damage awards. First, we eliminated

lawyer and attorney costs from patent infringement awards as possible as we can. Second, as our analyses are based on each patent instead of each patent case, we ascertained patent damage award for each patent by reading the decision carefully if the patent case involves more than one patent. In the case where patent infringement award for each patent are not written clearly, we calculated it simply by dividing the total patent infringement awards by the count of the patents judged to be infringed. Third, in regard to Japanese cases, the courts will not award the patent holder more than he has claimed according to the Japanese Code of Civil Procedure. Therefore, we took the calculated damages as patent infringement awards instead of the actual awards if the damages calculated by the court were more than the patent holder's claims. Fourth, when cases appealed to higher courts, patent infringement awards judged by the higher courts are used in our analyses. Fifth, to eliminate the effect of inflation on damage awards, we adjusted all patent infringement awards to 2010 US dollars (for the US cases), 2010 Japanese yen (for Japanese cases), and 2010 Chinese *yuan* (for Chinese cases) with the Consumer Price Index (CPI). We also adjusted Japanese and Chinese patent infringement awards to US dollars with purchasing power parity (PPP) and later to 2010 US dollars with CPI of US dollar in the comparison of patent infringement awards between the US, Japan and China, and the analysis of two mixture datasets including the US and Japanese patent infringement awards. Finally, as patent infringement awards in the US, Japan and China all follow lognormal distribution, we use natural logarithm of actual patent damages awards as the dependent variable.

Number of forward citations. Forward citations refer to citations received from subsequent patent applications. As technologies are usually cumulative, a large number of forward citations imply that the cited patent contributes greatly to the development of subsequent technologies and is of high technological importance. Trajtenberg (1990) found that the social value of patented invention shows highly positive correlation with patent counts weighted by number of forward citations. Albert *et al.* (1991) provided direct evidence to the argument that number of forward citations is highly correlated with a patent's technical importance. Moreover, a large number of forward citations may also indicate that the patented invention is viewed as commercially valuable by many innovators and is of high economic value. Harhoff *et al.* (1999, 2003) analyzed German patents and found that number of forward citations are highly correlated with the private economic value of the patent right, measured as the minimum price at which the patent owner would be willing to sell it. Yamada (2010) analyzed Japanese patents and found that number of forward citations are highly correlated with the probability of patent renewal. These studies can be summarized that a forward citation reflects technological value of the patent, and thus, often have a positive correlation with economic value of the patents. In our research design, forward citations are used as an indicator of technological value.

However, there are several problems with using raw citation counts directly (Hall *et al.*, 2001; Nagaoka *et al.*, 2010). First, forward citations often include a truncation bias. In other words, older patents are more likely to receive more citations than younger patents. Second, patent application counts and citation rate may change greatly over years and technological fields. We adopted a fixed-effect approach to eliminate these effects (Hall *et al.* 2001). Number of forward citations are normalized by dividing raw number of forward citations by average number of forward citations received by patents applied in the same year and by technology field (4-digit IPC code). Finally, we did not include number of forward

citations in the regression of Chinese patent infringement awards because of the lack of forward citation information of Chinese patents.

Family size. Family size refers to the number of countries in which patent for the same invention have been applied for. As an international patent application is far more costly than a domestic one, patent applications in multiple countries convey the innovator's high expectation of return from the patented technology (Nagaoka *et al.*, 2010). Putnam (1996) proposed family size as an indicator of the value of patent right for the first time. Lanjouw *et al.* (1998) reported that weighted patent counts based on family size can remove the noise in simple patent counts when being used to estimates patent value. Harhoff *et al.* (2003) further validated this Putnam's proposal by reporting that family size shows high correlation with economic value of a patent, which is measured as the minimum price at which the inventor of the patented technology would be willing to sell the patent right. Unlike number of forward citations, it is difficult to imagine that an innovator would patent his technology in many countries at great expense just for its technological value. On the other hand, no studies on the correlation between family size and technological value of patent have been reported thus far. Therefore, we consider family size as an indicator of economic value of patent in this study.

Number of IPC codes. Patents are assigned to 9-digit International Patent Classification (IPC) codes. As a patent may belong to several different technological fields, it may be assigned more than one IPC codes. Lerner (1994) used the number of 4-digit IPC codes for a patent as an indicator of patent scope and patent scope and reported that patent scope significantly correlates with market value of biotechnological firms. However, this sort of correlation between value of a patent and number of its assigned 4-digit IPC codes fails to be validated in patent level in later studies (Harhoff *et al.*, 2003, 2004; Lanjouw and Schankerman, 2001). In this study, we argue that multiple IPC codes for a patent indicate that the patented technology can be utilized in multiple areas. Therefore, instead of 4-digit IPC codes, we used the number of 9-digit IPC codes for the focal patent as an indicator of breadth of utilities.

Jury dummy and willfulness dummy. Jury system and enhanced damage system are two distinct systems that do not exist in Japan and China. As mentioned above, juries tend to awards higher patent damages than the judges. Moreover, if an act of infringement is considered to be willful, US judges will enhance damages up to three times the actual amount proven. Therefore, both these two factors can explain the variation in patent infringement awards ruled by the US courts. In this study, we added jury dummy and willfulness dummy to examine if they can also explain the difference in patent infringement awards between the US and Japan. If a patent damage award is ruled by juries, the jury dummy takes the value of 1, and otherwise it takes 0. If enhanced damages are awarded in a patent litigation, willfulness dummy takes the value of 1, and otherwise it takes 0.

Age of patent. An older patent is likely to have been infringed for a longer time. In this study, we calculated patent age in years by subtracting the year of patent application from the filed year of the lawsuit.

Number of claims. Patents with more claims are usually more costly in both the stage of patent application and patent renewal. Theoretically, number of claims can be an indicator of patent value, but this argument lacks adequate empirical evidence (Reitzig, 2004). On the other hand, the more number of claims is, the better the patent is protected. Therefore, number of claims may be an indicator of patent quality rather than patent value. Anyway, we use number of claims as a control variable in our analysis.

Number of lawyers and number of patent attorneys. Plaintiffs' and defendants' efforts may influence patent infringement awards. We used number of the plaintiff's lawyers, number of the plaintiff's patent attorneys, number of the defendant's lawyers, and number of the defendant's patent attorneys to control these effects in the analyses of Japanese and Chinese patent infringement awards. For the US patent cases, we cannot make a distinction between lawyers and patent attorneys according to the decision, so we used total number of lawyers and patent attorneys to do the regression analyses.

Year dummy and technology dummy. Although we tried to eliminate year effect and technological effect from number of forward citations, innovations of different technological fields may differ greatly in market size and the courts may also take different approaches to award patent damages in different years. Therefore, year dummy variable and technology dummy variable are also used in the regression models. Technology dummy variable is defined by the section symbol of the first IPC code assigned when patent right is granted.

Court dummy. Court dummy was also added in the models to test whether patent infringement awards granted by different courts are significantly different. In the regression of Chinese patent infringement awards, we classified courts according to the administrative area because the courts in the same administrative area may have the same policy of awarding patent damages.

6. Descriptive statistics of patent infringement awards

Table 2 shows some detailed statistical quantities of patent infringement awards in the three countries. We can see that differences among the US, Japanese, and Chinese patent infringement awards become larger and larger from the first quartile to the third quartile. The first quartile of US patent infringement awards is more than those of Japanese and Chinese patent infringement awards by only one digit. When it comes to the third quartile, US patent infringement award is more than Japanese patent infringement awards by two digits and more than Chinese patent infringement award by three digits. From this analysis, it can be inferred that in comparison with US courts, Japanese and Chinese courts, especially the latter, tend not to award high level of damages for patent infringements.

7. Empirical results

We examined correlations between variables before doing the regression analyses and found that number of plaintiff's lawyers and attorneys are highly correlated with number of defendant's lawyers and attorneys in all the datasets containing US patent infringement awards (with correlation coefficients about 0.6). To avoid the multicollinearity problem, we excluded number of plaintiff's lawyers and attorneys in

the regression models of these datasets.

Table 3 shows the regression results for the total US patent infringement awards. Family size significantly positively correlates with US patent infringement awards in both models 2 and 3. This is consistent with our Hypotheses 2. However, contrary to our expectation, US patent infringement awards are not significantly correlated with number of forward citations. This result is different from the regression result reported by Mazzeo *et al.* (2013), which finds that US patent infringement awards significantly positively correlates with average number of forward citations of the patents-in-suit. The difference may arise because (1) our regression are based on patent infringement awards for each patent instead of each patent case, and (2) we used the fixed effect approach to control the year effect and technological effect on number of forward citations. Moreover, jury dummy significantly positively impacts the amount of US patent infringement awards, which confirms findings by Mazzeo *et al.* (2013). Besides, age of patent-in-suit and willfulness dummy also significantly positively correlates with US patent infringement awards. Number of defendant's lawyers and attorneys are also significantly positively correlated with US patent infringement awards. In fact, if number of plaintiff's lawyers and attorneys is added in the model instead of number of defendant's lawyers and attorneys, its coefficient is also significantly positive. However, these results may be due to a known bias. Both the plaintiff and defendant will make greater efforts, such as using many lawyers and patent attorneys to defend themselves in patent litigation where a large amount of damages is involved. Furthermore, it seems that the courts in New Jersey and the Court of Appeals for the Federal Circuit (CAFC) award significantly higher patent infringement awards than Texas (baseline of court dummies) and other courts. We should not, however, focus more on this because there are only six patent cases decided in New Jersey in our dataset and higher amount of patent damage awards by CAFC may be due to selection bias.

Tables 4 and 5 display the regression results for US patent infringement awards ruled by judges, and those ruled by juries, respectively. Table 4 shows that family size and number of IPC codes significantly positively correlate with patent infringement awards ruled by judges. These results affirm our hypotheses 2 and 3. However, both the coefficients of these two variables are not significant in the regression of patent infringement awards ruled by juries in Model 5. This can also explain why the coefficient for number of IPC codes is not significant in the regression of total US patent infringement awards but significant in the regression of those ruled by judges. Number of forward citations significantly positively correlates with US patent infringement awards in Model 5. This is consistent with our Hypotheses 1. Moreover, approximately 47% of the variation in patent infringement awards ruled by judges can be explained by the independent and control variables. Compared with that, only approximately 29% of the variation in patent infringement awards decided by juries can be explained by the same set of variables. This indicates that patent infringement awards decided by juries are significantly less predictable than patent infringement awards ruled by judges, which is consistent with our Hypotheses 4.

Table 6 shows the regression results of Japanese patent infringement awards. We added all the variables into Model 3 and excluded family size from Model 1 and number of forward citations from Model 2. Number of forward citations significantly positively correlate with Japanese patent infringement awards in models 1 and 3. This is consistent with our Hypotheses 1. However, both family size and number of IPC codes do not show significant correlation with Japanese patent infringement awards. Moreover, like the regression results of US patent infringement awards, age of patent–in-suit and number

of defendant's patent attorneys are significantly positively correlated with Japanese patent infringement awards. Furthermore, although the coefficient for Osaka District Court dummy is significantly negative in Model 2, this result is unstable in models 1 and 3. Therefore, it can be concluded that no significant differences are observed between patent infringement awards decided by Tokyo District courts (baseline of court dummies) and those decided by other courts.

Table 7 shows the regression results of Chinese patent infringement awards. Model 1 displays the regression result of the dataset of all the samples. To test the robustness of the results, we excluded some samples decided by the courts outside Guangdong, Peking, Shanghai, Zhejiang, and Jiangsu from Model 2. In Model 1, the coefficients of family size and number of IPC codes are significantly positive. This is consistent with hypotheses 2 and 3. As in Japan and the US, number of defendant's patent attorneys is also significantly positively correlated with patent infringement awards in China. However, unlike in Japan and the US, age of patent-in-suit has no significant effect on patent infringement awards in China. Moreover, the coefficients of court dummies of Peking and Zhejiang are significantly positive. This means that the courts in Peking and Zhejiang award significantly higher patent damages than the courts in Guangdong which is the baseline of court dummies. Furthermore, the coefficients of court dummies of Peking and Zhejiang are significantly positive. This means that the courts in Peking and Zhejiang award significantly higher patent damages than the courts in Guangdong which is the baseline of court dummies. Model 2 provides similar results except for number of IPC codes and number of defendant's patent attorneys, the coefficients for which become insignificant.

Table 8 shows the regression results of two mixture datasets of patent infringement awards decided by US and Japanese courts. Model 1 uses the total mixture dataset, and Model 2 excludes some samples that were ruled by juries or/and awarded enhanced damages. The coefficient for jury system is significantly positive but the coefficient for willfulness dummy is not significant in Model 1. This indicates that jury system can explain the difference in patent infringement awards between the US and Japan which is consistent with our hypotheses 5, but enhanced damage system cannot explain it. On the other hand, the coefficients of all the US court dummies are significantly positive even if jury dummy and enhance damage dummy are controlled in Model 1. We get the same result in Model 2 where samples decided by juries or awarded enhanced damages are excluded from the regression dataset. All these results indicate that there exist some other important factors that lead to higher patent infringement awards in the US.

8. Discussion and conclusion

This study investigates three aspects of patent infringement awards in the US, Japan, and China.

First, this study clarifies correlations between patent value and patent infringement awards in the three countries. Overall, US patent infringement awards highly correlate with family size but show no correlation with family size and number of IPC codes. However, regression results differ if we split the dataset into two smaller datasets according to whether they are decided by juries or not. Our findings show that US patent infringement awards ruled by judges significantly positively correlate with family size and number of IPC codes of a patent-in-suit and those decided by juries significantly positively correlate with number of forward citations but show no significant correlation with family size and

number of IPC codes. As noted above, number of forward citations can be both an indicator of technological value of patents and an indicator of economic value of patents. Therefore, if we just see the regression result of number of forward citations, we cannot tell whether US patent infringement awards decided by juries are correlated with the economic value of a patent-in-suit. However, if we see the regression results of both number of forward citations and family size, we can conclude that judges and juries in the US attach weight to different aspects of patent value when they determine patent damages. Judges in the US attach weight to the economic value of a patent-in-suit and breadth of utility of a patent-in-suit and juries in the US attach weight to technological value of a patent-in-suit when they determine patent damages. Moreover, our findings also show that the same with US juries, judges in Japan also attach weight to technological value of a patent-in-suit. On the other hand, like US judges, Chinese judges attach weight to both economic value and breadth of utility of a patent-in-suit when they determine patent infringement awards. Chinese patent infringement awards have long been criticized as so low that the patentee may suffer damages even if he wins the litigation. This criticism may be true, so the Chinese Patent Law is being revised for the fourth time. However, the correlation between patent infringement awards and patent value should be maintained regardless of how the law is revised.

Second, we examined two possible factors that may explain the lower patent infringement awards in Japan than in the US. The jury system and enhanced damages are two special systems that do not exist in Japan and China. In this study, we find that jury system indeed has explanatory power to the variation in US patent infringement awards but enhanced damages system does not. Furthermore, even if we controlled the effect of the jury system and enhanced damages by using them as control variables or eliminated it by excluding the samples decided by juries or/and awarded enhanced damages, patent infringement awards decided in any of the US courts are still significantly higher than Japanese patent infringement awards. This means that except the jury system (and enhanced damages), there are also some other determinants that lead to its higher patent infringement awards in the US.

Third, this study finds that patent infringement awards decided by juries are systematically unpredictable than those ruled by judges. This result recalls the question whether patent juries are qualified to decide patent litigation cases. This study provides empirical evidence that juries are incompetent to decide patent infringement awards.

We should admit that there are two limitations in this study. First, although this study finds that courts in the US, Japan and China attach different weights to the two aspects of patent value when deciding patent infringement awards, it is difficult to say which is better or best. Future research should be conducted to clarify whether these different patent infringement award systems can encourage R&D investment and patent application, and enhance patentees' confidence of the enforceability of patent rights. Second, we discussed only two potential factors that may explain the difference in patent infringement awards between the US and Japan. Further research should be done to discuss other potential factors that lead to higher patent infringement awards in the US.

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Table 1

Distributions of patent cases by decision year.

Decision Year	US	Japan	China
2000	3	6	
2001	4	11	
2002	10	13	
2003	8	3	7
2004	20	10	4
2005	13	7	13
2006	11	3	16
2007	19	12	26
2008	11	8	50
2009	19	6	56
2010	21	5	57
2011	17	4	52
2012	15	9	86
2013		7	73
2014		19	68
Total	171	123	508

Table 2

Comparison of patent infringement awards between the US, Japan and China (2010 US dollar).

Nation	Minimum	First quartile	Median	Third quartile	Maximum	Mean	S.D.	Obs.
US	1,873	500,000	3,132,855	13,083,960	575,283,461	18,698,211	57,410,946	252
Japan	44	27,201	170,429	806,029	22,068,481	1,282,778	3,266,108	131
China	1,292	15,878	31,515	64,974	1,500,150	67,754	128,271	508

Table 3

OLS regression results for Log (US patent infringement awards)

	Model 1		Model 2		Model3	
Intercept	11.874***	(1.105)	11.455***	(1.109)	11.452***	(1.112)
Age of patent -in-suit	0.093***	(0.026)	0.096***	(0.026)	0.095***	(0.026)
Forward citations	0.023	(0.030)			0.009	(0.030)
Family size			0.049**	(0.021)	0.047**	(0.021)
Number of IPC codes	0.177	(0.168)	0.233	(0.166)	0.226	(0.168)
Number of claims	0.006	(0.006)	0.005	(0.006)	0.004	(0.006)
Defendant's lawyers and attorneys	0.182***	(0.035)	0.168***	(0.035)	0.167***	(0.036)
Jury	0.955***	(0.293)	0.997***	(0.290)	0.995***	(0.291)
Willfulness	0.620**	(0.273)	0.621**	(0.270)	0.622**	(0.270)
Court dummy						
California	0.261	(0.462)	0.274	(0.455)	0.286	(0.458)
Delaware	0.352	(0.482)	0.293	(0.477)	0.292	(0.478)
New Jersey	2.045***	(0.623)	2.090***	(0.616)	2.092***	(0.617)
New York	0.226	(0.688)	0.052	(0.683)	0.062	(0.686)
CAFC	1.815**	(0.757)	1.882**	(0.744)	1.856**	(0.751)
Others	-0.399	(0.394)	-0.308	(0.392)	-0.301	(0.393)
Technological dummy	Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes	
R^2	0.459		0.471		0.471	
Adjusted R^2	0.380		0.394		0.391	
Observations	252		252		252	

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4

OLS regression results for Log (US patent infringement awards ruled by judges)

	Model 1		Model 2		Model3	
Intercept	10.409***	(0.960)	10.438***	(0.931)	10.094***	(0.949)
Age of patent -in-suit	0.111***	(0.034)	0.094***	(0.033)	0.106***	(0.033)
Forward citations	-0.035	(0.039)			-0.065	(0.040)
Family size			0.057**	(0.028)	0.071**	(0.029)
Number of IPC codes	0.379**	(0.187)	0.421**	(0.185)	0.472**	(0.187)
Number of claims	0.009	(0.007)	0.004	(0.007)	0.007	(0.007)
Defendant's lawyers and attorneys	0.300***	(0.053)	0.255***	(0.051)	0.277***	(0.053)
Willfulness	0.534	(0.341)	0.585*	(0.337)	0.567*	(0.335)
Court dummy						
California	0.322	(0.602)	0.440	(0.593)	0.379	(0.590)
Delaware	-0.650	(0.631)	-0.398	(0.628)	-0.432	(0.625)
New Jersey	2.061***	(0.738)	2.235***	(0.730)	2.206***	(0.725)
New York	0.629	(0.846)	0.595	(0.834)	0.486	(0.831)
CAFC	1.956**	(0.852)	1.893**	(0.835)	2.056**	(0.835)
Others	-0.408	(0.532)	-0.232	(0.526)	-0.292	(0.524)
Technological dummy	Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes	
R^2	0.565		0.577		0.586	
Adjusted R^2	0.459		0.474		0.481	
Observations	152		152		152	

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5

OLS regression results for Log (US patent infringement awards ruled by juries)

	Model 1		Model 2		Model3	
Intercept	13.882***	(1.451)	14.350***	(1.463)	13.803***	(1.468)
Age of patent -in-suit	0.054	(0.051)	0.065	(0.052)	0.054	(0.051)
Forward citations	0.096*	(0.051)			0.095*	(0.052)
Family size			0.020	(0.037)	0.018	(0.036)
Number of IPC codes	-0.149	(0.403)	-0.166	(0.415)	-0.171	(0.408)
Number of claims	-0.001	(0.013)	0.005	(0.012)	-0.002	(0.013)
Defendant's lawyers and attorneys	0.169***	(0.060)	0.173***	(0.063)	0.161**	(0.062)
Willfulness	1.244**	(0.521)	1.208**	(0.534)	1.231**	(0.525)
Court dummy						
California	-0.063	(0.764)	-0.181	(0.780)	-0.034	(0.771)
Delaware	1.100	(0.812)	1.143	(0.845)	1.021	(0.833)
New Jersey	2.177*	(1.262)	2.111	(1.291)	2.164*	(1.269)
New York	-0.137	(1.247)	-0.250	(1.285)	-0.211	(1.264)
Others	-0.426	(0.674)	-0.526	(0.691)	-0.381	(0.684)
Technological dummy	Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes	
R^2	0.512		0.489		0.514	
Adjusted R^2	0.304		0.272		0.296	
Observations	152		152		152	

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6

OLS regression results for Log (Japanese patent infringement awards)

	Model 1		Model 2		Model 3	
Intercept	12.403***	(1.301)	13.095***	(1.327)	12.417***	(1.306)
Age of patent-in-suit	0.078*	(0.040)	0.088**	(0.042)	0.081**	(0.040)
Number of forward citations	0.210***	(0.075)			0.207***	(0.075)
Family size			0.055	(0.077)	0.041	(0.075)
Number of IPC codes	0.077	(0.125)	0.022	(0.132)	0.061	(0.129)
Number of claims	0.017	(0.054)	0.038	(0.057)	0.009	(0.056)
Number of plaintiff's lawyers	0.015	(0.131)	0.025	(0.138)	0.001	(0.134)
Number of plaintiff's attorneys	0.230	(0.191)	0.202	(0.203)	0.206	(0.197)
Number of defendant's lawyers	-0.067	(0.109)	-0.040	(0.112)	-0.067	(0.109)
Number of defendant's attorneys	0.776***	(0.202)	0.770***	(0.210)	0.781***	(0.203)
Court dummy						
Osaka District Court	-0.748	(0.559)	-1.091*	(0.566)	-0.749	(0.561)
Nagoya District Court	-0.218	(2.594)	-0.687	(2.686)	-0.203	(2.604)
Tokyo High Court	-1.306	(1.604)	-0.861	(1.666)	-1.426	(1.624)
Osaka High Court	-0.667	(1.574)	-0.706	(1.647)	-0.549	(1.594)
IP High Court	-0.415	(0.741)	-0.868	(0.750)	-0.415	(0.744)
Technological dummy	Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes	
R^2	0.467		0.426		0.469	
Adjusted R^2	0.278		0.223		0.273	
Observations	131		131		131	

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 7

OLS regression results for Log (Chinese patent infringement awards)

	Model 1		Model 2	
Intercept	10.736***	(0.497)	9.926***	(0.551)
Age of patent	-0.008	(0.013)	-0.004	(0.015)
Family size	0.022**	(0.009)	0.015*	(0.009)
Number of IPC codes	0.073**	(0.033)	-0.005	(0.040)
Number of claims	0.003	(0.004)	0.002	(0.006)
Number of plaintiff's lawyers	0.032	(0.063)	0.069	(0.068)
Number of plaintiff's attorneys	-0.047	(0.124)	-0.003	(0.119)
Number of defendant's lawyers	0.083	(0.055)	0.057	(0.060)
Number of defendant's attorneys	0.324**	(0.163)	0.226	(0.168)
Court dummy				
Peking	0.646***	(0.187)	0.789***	(0.177)
Shanghai	-0.180	(0.168)	-0.224	(0.158)
Zhejiang	0.539***	(0.165)	0.465***	(0.155)
Jiangsu	0.358	(0.244)	0.294	(0.226)
Others	0.336**	(0.155)		
Technological dummy	Yes		Yes	
Year dummy	Yes		Yes	
R^2	0.224		0.268	
Adjusted R^2	0.173		0.203	
Observations	508		368	

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8

OLS regression results for Log (the US and Japanese patent infringement awards)

	Model 1		Model 2	
Intercept	10.432***	(0.794)	10.839***	(1.089)
Age of patent -in-suit	0.072***	(0.022)	0.055*	(0.028)
Forward citations	0.055*	(0.029)	0.128***	(0.045)
Family size	0.052**	(0.022)	0.084**	(0.037)
Number of IPC codes	0.096	(0.087)	-0.014	(0.101)
Number of claims	0.006	(0.007)	-0.019	(0.014)
Defendant's lawyers and attorneys	0.128***	(0.035)	0.122**	(0.056)
Jury	0.837***	(0.321)		
Willfulness	0.462	(0.305)		
Court dummy				
Texas	2.251***	(0.522)	4.673***	(0.879)
California	2.361***	(0.468)	2.460***	(0.750)
Delaware	2.684***	(0.547)	1.913**	(0.880)
New Jersey	4.230***	(0.701)	5.505***	(0.932)
New York	1.987***	(0.724)	3.010***	(1.092)
CAFC	3.904***	(0.726)	3.964***	(0.956)
Others	1.785***	(0.412)	1.935***	(0.605)
Technological dummy	Yes		Yes	
Year dummy	Yes		Yes	
R^2	0.505		0.520	
Adjusted R^2	0.434		0.431	
Observations	383		219	

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix

■ US patent infringement awards

Section 284 of the United States Patent Act provides that the court shall award the claimant damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer, together with interest and cost as fixed by the court (35 U.S.C. § 284.). This statute provides two optional methods for calculating patent damages; lost profits and reasonable royalty. In some cases, a combination of the two optional calculation methods can be used in the same litigation (Love, 2009). If the courts finds the willful infringement, they can award treble enhanced damages. This means that they can increase the damages up to three times the amount of damages found or assessed.

Lost profits are usually higher than reasonable royalty in most cases. However, to obtain lost profits, you must establish the causation between infringement acts and damages. In the US, the *Panduit* test was established by the 6th Circuit to determine "but for" causation (Frank and DeFranco, 2000). To obtain lost profits, a patentee must establish the four requirements of the *Panduit* "but for" test: (1) market demand for the product covered by the patented technology; (2) an absence of non-infringement substitutes to satisfy the demand in the same market; (3) the patentee's manufacturing and marketing capacity to exploit the demand; and (4) the amount of profits that the patentee would have made if infringement had not occurred (Frank and DeFranco, 2000; Love, 2009).

Reasonable royalty is the amount that the patentee would have earned if both the patentee and infringer had been willing and had tried to negotiate to license the patent at the beginning of the infringement (Love, 2009). However, reconstructing this hypothetical negotiation is a difficult task. In *Georgia-Pacific Corp. v. United States Plywood Corp*, the US District Court for the Southern District of New York summarized 15 factors that might be considered in a hypothetical negotiation analysis (Frank and DeFranco, 2000). The 15 factors, often called the *Georgia-Pacific* test, are now the most commonly used standard for US courts to calculate reasonable royalty. An alternative method of calculating reasonable royalty damages is the "analytical approach," under which the infringer's profit projection relating to the infringing product or process are apportioned between the patentee and infringer (Opderbeck, 2009).

□ Japan patent infringement awards

Before 1998, the Japanese Patent Act provided only two options for calculating patent infringement damages: defendant's profits and reasonable royalty. If a patentee wanted to recover his lost profits, he had to claim damages under Article 709 of Japanese Civil Code, which requires the patentee to prove causation between his lost profits and the defendant's act of infringement. However, since the patent is an intangible property, it is extremely difficult for the patentee to prove causation. Therefore, to reduce the plaintiff's burden of proof, Japanese lawmakers revised Article 102 of the Japanese Patent Act in 1998 by adding a new provision for calculating the patentee's lost profits. Therefore, the current Japanese Patent Act provides three optional calculation methods of patent damages: patentee's lost profits, defendant's profits and reasonable royalty.

Unlike the US Patent Act, according to the new provision, patentee's lost profits in Japan are calculated by multiplying patentee's own profit of a single product and defendant's quantity of sales of the infringing product instead of patentee's reduced quantity of sales for the infringement. The patentee only needs to show two facts to get lost profit awards: (1) the capability to manufacture and sell, and (2) the patentee's own profit of a single product and the number of infringing products (Takenaka, 2000). Although this provision still requires the patentee's exploitation

of the patented technologies, this change shift the burden of proof to the defendant's party so greatly that it is believed that recovery of lost profits in Japanese courts after 1998 will become easier than that before 1998 or even easier than that in US courts.

The method of defendant's profits was once provided in the US patent statute but was eliminated in 1946 because it was considered to be redundant with lost profits and was difficult to establish (Takenaka, 2000). In Japan, defendant's profits are calculated by multiplying defendant's profit of a single product and defendant's quantity of sales of the infringing product. As is the case with patentee's lost profits, this method requires that the patentee exploits, manufactures, and sells products covered by the patent-in-suit. Since the infringed products may usually be sold at a lower price than the patentee's non-infringed products, the patentee may obtain a lower amount of compensation in the form of defendant's profits than in the form of patentee's lost profits.

The third calculation method is reasonable royalty. Before 1998, the patentee's prior royalty rate of the patent-in-suit or license royalty rates of government-owned patents or industry-standard royalty rates were often used as a reasonable royalty. However, in these cases, the infringer may just pay the same or smaller amount of money to the patentee even if they fail in the litigation. This will give no deterrent force to the infringer-in-suit and other potential infringers or even give them incentives not to apply for a license before they use other innovators' patents. Japanese lawmakers therefore revised Article 102 of the Japanese Patent Act in 1998 and now allow the courts to consider the value of the patent-in-suit, the commercial relation between the patentee and defendant, defendant's profits, and other related matters when they decide a reasonable royalty.

- Chinese patent infringement awards

The Chinese Patent Law provides four options for calculating patent damages patentee's lost profits, defendant's profits, an appropriate multiple of prior license royalty of the patent-in-suit, and statutory compensation.

In principle, the first two options shall be preferably considered to calculate damages. Patentee's lost profits can be calculated by multiplying patentee's profits of a single product and patentee's reduced quantity of sales for the infringement or defendant's quantity of sales of the infringing product if the patentee's reduced quantity of sales for the infringement cannot be ascertained. Defendant's profits are calculated by multiplying defendant's profits of a single product and quantity of sales of the infringing product.

If patentee's lost profits and defendant's profits cannot be proved or ascertained and the patentee has licensed the patent-in-suit ever before, an appropriate multiple, usually one to three times, of the prior royalty rate of the patent-in-suit shall be used to calculate damages (Benjamin *et al*, 2006). If there is no prior royalty rate or the established royalty is obviously unreasonable, the court can award statutory compensation by considering the type of the patent-in-suit, intention of the infringement, extent of the infringement, and other related factors. The Chinese Patent Law during the period of 2000 to 2008 provided that statutory compensation should usually be restricted within the range of RMB 5 thousand to RMB 30 thousand and that it should never exceed RMB 500 thousand. After being revised in 2008, the current Chinese Patent Law provides that statutory compensation should usually be restricted within the range of RMB 10 thousand to RMB 30 thousand and that it should never exceed RMB 1 billion.