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How to forecast cross-border patent infringement? — The case of U.S. international trade

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ABSTRACT

The International Trade Commission is one venue for enforcement of United States Patents, the other venue being the Federal District Courts. The ITC conducts investigation on unfair methods of competition and unfair acts in the importation under United State Section 337. The majority of ITC investigations are based on the importation of goods that are alleged to infringe a United States patent. This paper seeks to investigate fundamental characteristics of patents investigated by ITC, name as "ITC patent" in this study, from 1976 to 2012 in order to obtain early precaution of possible ITC investigation for newly filed patents. Patents which have been investigated by ITC are defined as ITC patents (1305 patents) and those which have never been investigated by ITC defined as non-ITC patents (4,388,043 patents). Both ITC patents and non-ITC patents are analyzed to understand the differences between the two types of patents in terms of 11 variables. Subsequently, the difference between ITC patents and non-ITC patents in a manner that is statistically different from random distribution will be identified. Furthermore, regression model is used to test whether each of the above variables (the 16 indicators) is related to each other and evaluate the probability of being investigated by ITC.

1. Introduction

The most important feature of a patent is to protect intellectual property right in the knowledge economy [1]. The degree to which a patent can protect its intellectual property right is proportional to its patent value which has been rigorously studied [2–4]. The value of a patent relies heavily on the characteristics of the patent, and it is widely accepted that one of the most important characteristics, in terms of value, of a patent is whether or not a patent has been involved in infringement [5,6]. It can be observed that the number of patent infringement disputes has been increasingly remarkably over the past two decades [7][8][5]. In the US, there had been a total of 37,317 disputed patents since 1976 to 2012, these disputed patents comprise 36,905 patents investigated by the US courts and 1305 patents investigated by the International Trade Commission (ITC) [9].

Patent as one of the important documents for protecting intellectual property in a knowledge economy plays a very significant role in an infringement [10]. Unlike most of non-infringed patents, an infringed patent is practically used to protect intellectual property and it is quite straightforward to hypothesize that infringement chance is positively related to patent value. Actually, the hypothesis has been verified by literatures. For example, Allison et al. (2004) argued that litigated patents are patents of higher value and their characteristics are fundamentally different from those without being used in litigated, i.e. non-litigated patent [5].

Cook (2007) argued that it is important to differentiate both infringed-patent and non-infringed patent to understand technological competition [11]. Also, even some methods have been proposed in literatures to assess probability of patent infringement, for example, by ways of real option [12], fuzzy method

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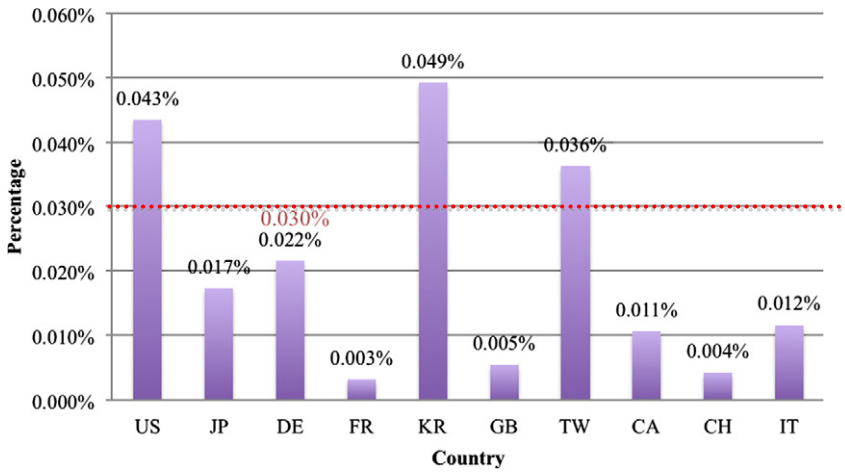

Fig. 1. Percentage of ITC patents in top 10 fist assignee countries (top 10 countries with highest numbers of patents, dashed line shows the average is 0.030%).

[13,14], or combination of both [15]. Some researches focused on infringements in some selected industries. For example, textiles, combustion engines, and pharmaceuticals, Software, computers, Semiconductor, Mechanical, Electronics, Optics, Imaging, Biotechnology, Chemistry [5][16–19].

Patent infringements can be classified into two types. One type of patent infringement is investigated by the court, the other type is cross-border patent dispute investigated by the International Trade Commission (ITC). ITC was established in 1916 as U.S. Tariff Commission and changed to International Trade Commission in 1974, it has broad investigation power on infringements of trade, e.g. Patent, Copyright, Trademark and Trade secret. ITC as the government agency dealing with cross-border patent infringements plays a much more important role in international trading and global economy than the court dealing with domestic patent dispute. From 1976 to 2012, ITC had investigated 1305 patents defined as "ITC patents" in this study that have never been characterized in the literatures. Especially when it comes to the difference between ITC patents and non-ITC patents, such investigation is not yet available in the literatures.

Therefore, this study seeks to fill the gap in the literature by conducting holistic scale analysis on ITC patents, i.e. all utility patents in USPTO database from 1976 to 2012 are classified into two both ITC patents and non-ITC patents. Subsequently, multivariate analysis and regression analysis are adopted in this study in order to characterize patents and reach the purpose of this paper as disclosed in this paper title "How to Forecast Cross-Border Patent Infringement?", seeking to provide a method to forecast Cross-Border Patent Infringement?

More specifically, the purpose of this paper is to use some important patent characteristics to forecast probability of Cross-Border Patent Infringement, which can be correlated to patent value, by answering the following two questions: 1) What are the characteristic differences between ITC patent and non-ITC patent, 2) how a patent's characteristic influences the probability of cross-border patent infringement?

2. Patent value and patent infringement

The use of patent in protecting intellectual property has been getting more and more important in the development of a knowledge economy. Besides the protection of intellectual property, patent can also be used to measure innovation capacity of a country or an enterprise [20], market value of intellectual and intangible asset portfolio [21]. Patent valuation has been a key research topic for academic researchers as well as a mean for patent assignee to formulation business strategies [22]. In a growing knowledge economy, how to objectively evaluate paten value has become a key factor for sustaining innovative competitiveness.

To evaluate value of patents, Reitzig (2004) validated indicators of patent value by analyzing application rationales and found some useful indicators, i.e. patent age, forward citation, backward citation, patent family size, technological range, number of claims, etc [23,24]. However, "Value" is a not a fixed price but an abstract concept as a function of very many factors and different dimensions. Patent is an official document to legally protect invention so legal value is essential for a patent. Also, patent defines and protects the scope of a technological invention so technological value is of no doubt inherent in a patent document. Further, the technology protected by patent can be commercialized to create economic value and allow patent owner to monopolize the market. Therefore, patent value can be investigated from three different dimensions, i.e. 1) legal value [25,26][17] [27–30][15], 2) technology value [31–34] and 3) economic value [35–40]. Also, the evaluation of the three values by different indicators has been discussed by Gibbs [41] and Zhang et al. [24].

As the growing globalization of business activities, enterprises seek to use infringement-based business strategies to prevent competitors from entering into the market by patent. The value of patent with exclusive right fundamentally relies on the extent to which the invention can be protected from infringement. Evidence must be used to evaluate patent value

[42] and evidence such as patent infringement has been used as a way for patent valuation [43].

Patent infringement has been becoming a popular topic in recent years [42]. Allison, Lemley, Moore & Trunkey (2004) found that valuable patents comprise more claim, more forward citations, and more backward citation. Allison, Lemley & Walker (2009) characterized the most-litigated patents and found most-litigated patents are of higher market value [30]. It is generally accepted that infringed patents and valuable patents are correlated to each other. High value patent is involved in patent infringement more frequently.

It is possible to discover the potential of a patent to be involved in infringement in the future or to calculate infringement probability if patent attributes can be carefully characterized, and thus an infringement precaution method can be provided to quantitatively evaluate such infringement probability. Macro (2005) used some patent characteristics such as number of forward citation, number of backward citation, number of claim, as variables to create a real option model to investigate the validity and costly enforcement on patent [28]. Agliardi and Agliardi (2011) utilize fuzzy theory to construct the prediction model [15].

However, to characterize patents in an objective way, a holistic scan of all patents has to be done to understand how a patent can be positioned objectively in the "infringement possibility map" of a patent database containing all patents granted in the patent system. Therefore, it is required to handle such large set of patent data, which is no simple task at all. That is why studies in literature all focused on a small range of patent samples which are, for example, patents granted within a small period of time or patents chosen from a selected industry. Allison et al. compared most-litigated patents only with the control set of patents that are only litigated once [5]. However, in our previous study for domestic patent dispute in the US, we have successfully conducted holistic scale of analysis on 3,910,844 patents (all granted USPTO utility patents from 1976 to 2012), i.e. 3,878,852 non-litigated patents and 31,992 litigated patents, and successfully established a Patent Litigation Precaution Method based on the creation of a probability forecasting model for domestic patent infringement [6].

Due to the fact that patent characteristics from the perspective of cross-border patent infringement have never been investigated in literatures, this study seeks to fill the research gap by analyzing all 4,389,348 utility patents issued by USPTO from 1976 to 2012. Patents are classified into ITC and non-ITC patents, the characteristics of the two groups of patents are analyzed, and finally to establish precaution method, based on the creation of a probability forecasting model, for cross-border patent infringement.

Table 2
First assignee type.

Assignee type	ITC patent (%)	Non-ITC patent (%)
Individual	5.67	12.01
Company	91.34	80.08
Government	0.77	1.64
University	1.23	1.95
Hospital	0.08	0.12
Private non-profit	0.38	0.80
Other/Unknown	0.31	1.99

*indicated p-value < 0.1, **p-value < 0.05, ***p-value < 0.01.

3. Research method

US patents are used in this study and the US is selected as the target country to demonstrate how to forecast cross-border patent infringement because of two reasons: First, the US is the largest and most competitive market in the world. Thus, it is imperative for companies to obtain US patent protection for all their key inventions. Second, the USPTO has the largest collection of patents in the world, with extensive coverage of most technologies. As such, US patent data is one of the best available patent data to demonstrate forecasting cross-border patent infringement.

This study fist downloads all USPTO utility patents issued from 1976 to 2012 (4,389,348 utility patents in total). In the course of reviewing the literature [42][5][23][28][44], consulting with experts in this field, 14 important characteristics of patents are retrieved from every patent document and defined as variables of patents: 1) Patent Number, 2) Application Year, 3) Issue Year, 4) No. of Assignee, 5) No. of Assignee Country, 6) No. of Inventor, 7) No. of Inventor Country, 8) No. of Patent Reference, 9) No. of Patent Citation Received, 10) No. of IPC, 11) No. of UPC, 12) No. of Claim, 13) No. of Non-Patent Reference,

Table 1
Characteristics of ITC patent and non-ITC patent.

Variables	ITC patent	Non-ITC patent	t-test	p-value
No. of assignee	0.95	0.89	−7.51	0.0002***
No. of assignee country	0.94	0.87	−10.18	<0.0001***
No. of inventor	2.68	2.25	−6.75	<0.0001***
No. of inventor country	1.02	1.04	3.74	<0.0001***
No. of patent reference	32.67	14.59	−9.09	<0.0001***
No. of patent citation received	32.41	8.98	−14.01	<0.0001***
No. of IPC	4.43	4.03	−3.59	0.0704
No. of UPC	13.11	12.26	−3.84	0.0513
No. of claim	24.59	14.91	−14.83	<0.0001***
No. of non-patent reference	9.7551	2.8396	−5.82	0.0682
No. of foreign reference	5.2646	2.4497	−6.56	0.6051

*indicated p-value < 0.1, **p-value < 0.05, ***p-value < 0.01.

Table 3
ITC and Non-ITC patent counts for first assignee countries.

	No. of ITC patents	Share of ITC patents	No. of non-ITC patents	Share of non-ITC patents
USA	863	11.34%	1,988,659	45.32%
Japan	148	5.82%	857,657	19.55%
Germany	57	3.83%	265,047	6.04%
Korea	50	2.15%	101,501	2.31%
Taiwan	28	1.69%	77,059	1.76%
Finland	22	0.69%	18,297	0.42%
Sweden	9	0.54%	34,960	0.80%
Cayman Islands	7	0.46%	2257	0.05%
Canada	6	0.38%	56,490	1.29%
Israel	5	0.31%	13,983	0.32%

14) No. of Foreign Reference. Some variables that have nothing to do with patent value or patent infringement, i.e. 1) Patent Number, 2) Application Year, 3) Issue Year, are not considered in the characterization work conducted in this study, and therefore the following 11 variables remained and subsequently used in this study.

1. No. of Assignee
2. No. of Assignee Country
3. No. of Inventor
4. No. of Inventor Country
5. No. of Patent Reference
6. No. of Patent Citation Received
7. No. of IPC
8. No. of UPC
9. No. of Claim
10. No. of Non-Patent Reference
11. No. of Foreign Reference

In order to obtain the purpose of establishing precaution method for cross-border infringement, two hypotheses need to be tested in this study: 1) Significant difference can be observed between ITC patents and non-ITC patents, 2) Probability of cross-border infringement is related to characteristics of patents. Difference between ITC patents and non-ITC patents should be statistically significant, also the relation between probability of cross-border infringement and characteristics of patents should be confirmed to allow subsequent modeling work for the purpose of establishing precaution method for cross-border infringement.

To identify litigated patents, ITC patents are obtained from ITC official website. The database includes all patent infringements reported to the ITC from 1975 to date. What considered in this study are the total of 1305 ITC patents issued by USPTO from 1976 to 2012. This study conducts descriptive statistics, two sample *t*-test, ANOVA, to understand the characteristics of ITC-patents and the difference between ITC-patents and non-ITC patents. In addition, a regression analysis is subsequently conducted to model the probability of being investigated by ITC in order to obtain the purpose of cross-border infringement precaution.

4. Results—characterization of ITC patents and non-ITC patents

There are 4,389,348 utility patents and 31,992 litigated patents issued by USPTO from 1976 to 2012, the share of ITC patents is 0.0297%. Fig. 1 shows the top 10 countries with the largest volumes of patents. The position of the countries on the X-axis follows the number of total patents owned by each country, where the US is positioned on the left end and ranked as No. 1 and Italy is on the right end and ranked as No. 10 on the right end. For the top 10 first assignee countries, the percentages of ITC patents in the top 10 assignee countries are from France (0.003%) to Korea (0.0439%), US (0.049%), Korea (0.049%), US (0.043%) and Taiwan (0.036%) are above the global average (0.030%).

Two-sample *t*-test is conducted to calculate the difference between ITC patents and non-ITC patents for the aforementioned mentioned 11 variables. The results are provided in Table 1, statistical differences for the 11 variables are mostly significant, most of *p*-values are smaller than 0.0001. Four variables, i.e. No. of IPC, No. of UPC, No. of Non-Patent Reference, No. of Foreign

Table 4
ITC and Non-ITC patent counts for first inventor countries.

	No. of ITC patents	Share of ITC patents	No. of non-ITC patents	Share of non-ITC patents
USA	925	70.88%	2,324,676	52.98%
Japan	142	10.88%	865,936	19.73%
Germany	56	4.29%	302,906	6.90%
Korea	49	3.75%	103,804	2.37%
Taiwan	28	2.15%	104,748	2.39%
Finland	19	1.46%	17,623	0.40%
Canada	16	1.23%	90,170	2.05%
Belgium	12	0.92%	16,690	0.38%
France	9	0.69%	111,914	2.55%
UK	8	0.61%	110,743	2.52%

Table 5
ITC and Non-ITC patent counts for industries.

	No. of ITC patents	Share of ITC (%)	No. of non-ITC patents	Share of non-ITC patents
Electrical engineering/Computer technology	241	18.47%	310,587	7.08%
Electrical engineering/Telecommunications	120	9.20%	152,942	3.49%
Electrical engineering/Semiconductors	110	8.43%	164,148	3.74%
Electrical engineering/Audio-visual technology	101	7.74%	158,363	3.61%
Instruments/Optics	85	6.51%	197,967	4.51%
Electrical engineering/Electrical machinery, apparatus, energy	81	6.21%	229,343	5.23%
Instruments/Measurement	48	3.68%	199,012	4.54%
Instruments/Medical technology	48	3.68%	175,742	4.01%
Mechanical engineering/Transport	44	3.37%	165,087	3.76%
Mechanical engineering/Textile and paper machines	42	3.22%	980,62	2.23%

Note: IPC to Technology conversion table is provided by WIPO [27].

Reference, have *p*-value higher than 0.01. Significant differences between ITC and non-ITC patents can be observed in No. of Patent Reference, No. of Patent Citation Received, No. of Claim, No. of Non-Patent Reference, No. of Foreign Reference, this verifies prior literatures using citation, reference and claim as important indicators for patent valuation. On the opposite, there existed an assumption, which is easily accepted by most literatures, that co-patenting among inventors, companies, countries is an innovative behavior and thus should contribute to patent value, but this study shows that variable relevant to co-patenting, i.e. No. of Assignee, No. of Assignee Country, No. of Inventor, No. of Inventor Country, does not show significant difference between ITC and non-ITC patents. The co-patenting activity does not provide a significant effect to international trading infringement and thus its contribution to patent value is suspicious.

To test the difference between ITC patents and non-ITC patents for different types of assignees, this study categorizes first assignees of all patents into 1) Individual, 2) Company, 3) Government, 4) University, 5) Hospital, 6) Private non-profit, 7) Other/Unknown by the method proposed by Van Looy et al. [45]. The results are provided in Table 2, it can be observed that the portion of Company assignee is higher in ITC patents (91.34%) than in Non-ITC patents (80.08%), and the Individual assignee is lower in ITC patents (5.67%) than in Non-ITC patents (12.01%). The significantly large percentage of Company assignee in ITC patents is because of ITC's function of investigating cross-border trading dispute.

Table 3 shows the ranking of ITC and non-ITC patents for first assignee country. The US, Japan and Germany are the top three countries in terms of both ITC patents and non-ITC patents. Table 4 shows the ranking of ITC and non-ITC patents for first inventor country. The top three first assignee countries are again the US, Japan and Germany. The Top 5 countries in Table 4 are quite similar to those in Table 3, because the first assignee country is usually the same as the first inventor country in patent documents. From Tables 3 and 4, it can be observed that Asian countries play a very important role in international trading infringement with the US.

To understand patent infringement in industries, an IPC to Technology concordance table provided by WIPO [46] is used to convert the first IPC in the patent document to a corresponding industry in this study. As shown in Table 5, Most of ITC patents are from Electrical Engineering, Instrument and Mechanical Engineering. Despite the different ranking, the top 10 industries for ITC patents are also the top 10 industries in non-ITC patents except "Mechanical engineering/Textile and paper machines ". As the no. 1 industry in terms of ITC patents, the number of patents for "Electrical engineering/Computer technology" (241 patents) is more than double of "Electrical engineering/Telecommunications" (120 patents). This indicates the fast pace development as well as the rigorous international competition in Computer technology. Due to the limitation on availability of holistic patent data, prior literatures always focused on specific industries only, for example, textiles,

Table 6
Results of logistic regression.

Variable	Estimate	Standard error	Wald Chi-Square	*p*-value
Intercept	−8.5323	0.2120	1620.3516	<0.0001***
No. of assignee	−2.1167	0.5716	13.7138	0.0002***
No. of assignee country	2.7986	0.5833	23.0156	<0.0001***
No. of inventor	0.0940	0.0123	58.6540	<0.0001***
No. of inventor country	−0.9527	0.1853	26.4280	<0.0001***
No. of patent reference	0.0013	0.000321	16.5302	<0.0001***
No. of patent citation received	0.00572	0.000268	454.4390	<0.0001***
No. of IPC	0.0121	0.00657	3.4065	0.0649*
No. of UPC	0.0141	0.00222	40.5027	<0.0001***
No. of claim	0.0117	0.000715	269.7140	<0.0001***
No. of non-patent reference	0.00174	0.000419	17.2039	<0.0001***

*indicated *p*-value < 0.1, **p-value < 0.05, ***p-value < 0.01.

combustion engines, and pharmaceuticals, Software, computers, Semiconductor, Mechanical, Electronics, Optics, Imaging, Biotechnology, Chemistry [5][16–19]. Table 5 provides an industry-based overview on ITC and non-ITC patents and removes the limitation which has long existed in the literatures by making possible the holistic scale analysis on all patents in the perspective of cross-border infringement. The different ranking for ITC patents and non-ITC patents in Table 5 provides an evidence to show which industries play more critical roles in the development of knowledge economy.

5. Modeling for cross-border patent infringement precaution

Finally, in order to estimate the probability of cross-border patent infringement and obtain the purpose of establishing cross-border patent infringement method, regression analysis is conducted by fitting a function curve to the aforementioned patents characteristics of 4,389,348 USPTO utility patents, for calculating patents' probability of involving in ITC investigation. In this study, Logistic function is selected for the curve-fitting because the ITC patent data is binary-based, i.e. cross-border infringement probability is 1 if a patent has ever been investigated by ITC, cross-border infringement probability is 0 if a patent has never been investigated by ITC. However, according to the *t*-test results for the 11 variables provided in Table 1. No. of IPC does not show strong relations to probability of being investigated by ITC, because its *p*-value is the highest. Therefore, No. of IPC should not be considered in the model for forecasting cross-border patent infringement. The regression results are provided in Table 6 which shows that the rest 10 variables are significantly related to probability of Infringement (The *p*-values for all variables are all less than 0.001).

The obtained equation:

$$\text{Probability of Cross-Border Patent Infringement} = e^z/(e^z+1)$$

$$\begin{aligned} z = {} & -8.5323 - 2.1167 * (\text{No.of Assignee}) + 2.7986 * (\text{No.of Assignee Country}) \\ & + 0.0940 * (\text{No.of Inventor}) - 0.95270 * (\text{No.of Inventor Country}) \\ & + 0.0013 * 0.0013 * (\text{No.of patent Reference}) + 0.00572 \\ & * (\text{No.of Patent Citation Received}) + 0.0141 * (\text{No.of UPC}) + 0.0117 \\ & * (\text{No.of Claim}) + 0.00174 * (\text{No.of Non-Patent Reference}) \end{aligned}$$

6. Conclusion

This study conducts a holistic scale analysis on USPTO utility patents from 1976 to 2012, and characterizes them from the perspective of cross-border patent infringement. A total of 4,389,348 USPTO utility patents comprising 1305 ITC patents and 4,388,043 non-ITC patents are analyzed and characterized. A significant difference between ITC patents and non-ITC patents can be observed. Also, a logistic equation is obtained for assessing the probability of being investigated by ITC. As shown in the regression results and predicting model, No. of Assignee and No. of Inventor Country have a negative effect on the probability of ITC investigation. On the opposite, No. of Assignee Country, No. of Inventor, No. of Patent Reference, No. of Patent Citation Received and No. of Claim have a positive effect on the probability cross-border patent infringement investigated by ITC.

The obtained model can be used to evaluate patent values from the perspective of cross-border patent infringement for levels of country, industry and company. It is always a complex process to evaluate patent value or even patent value is usually based on negation without being calculated quantitatively and objectively. This study provides a model to obtain evidence-based patent valuation in terms of cross-border patent infringement. The higher probability of involving in cross-border patent infringement, the higher patent value can be expected.

In summary, this study conducts the modeling work for all utility patents granted by USPTO from 1976 to 2012 and proposed the first ever model to forecast cross-border patent infringement, as well as provided a legal based patent valuation method in the field of patent related research. However, due to the fact that this study concerns only the aforementioned 11 variables when modeling the ITC investigation probability, studies concerning different variables are suggested for future study in order to obtain the best model with minimized error in regression modeling. Also, the number of time each patent has been investigated by ITC is not considered in this study, and therefore is also suggested to be a possible trial for future study. The consideration of some other variables such as patent age, ITC investigation time, etc, can be carefully evaluated and incorporated by comparing the curve fitting errors in order to obtain a more precise model for precaution of ITC investigation.

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