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以倒傳遞神經網路建構專利法律價值的評價模型

Modeling Patent Legal Value by Back Propagation Neural Network

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摘要

本研究基於專利的法律本質，提出專利法律價值的評價模型。專利侵權訴訟的「判罰金額」被定義為專利可被量化的法律價值。經由調查美國德拉瓦州、加州與德州等三州聯邦地方法院的資料，得到4,289個專利相關訴訟案例，再藉由縝密的篩選得到65個具有判罰金額的有效樣本。本研究採用了17個量化的專利指標，經由因素分析將其縮減為9個萃取因子。由多元迴歸分析篩選出對判罰金額影響較為顯著的6個萃取因子。再倒傳遞神經網路建構專利評價模型，其中6個萃取因子作為輸入變數，判罰金額則為輸出變數。藉由誤差分析與驗證，此專利評價模型具有預測能力，可應用於評估專利訴訟所可能產生的判罰金額，並協助原告與被告兩造雙方的談判。

【關鍵字】專利鑑價、因素分析、倒傳遞神經網路

Abstract

This study aimed at the basis of patent law and proposed a valuation model for the monetary legal value of patents. The damage award of a patent infringement lawsuit was deemed to be the legal value of a patent. 65 Effective samples of infringement lawsuits were extracted from 4,289 patent related lawsuits in U.S. district courts of Delaware, California and Texas. 17 quantitative patent indicators were summarized to describe dimensions of a patent. 9 extracted factors were generated from the 17 patent indicators by Factor analysis. The multi-regression was applied to find the nonlinearity between the damage award and 9 extracted factors. 6 extracted factors which having higher influence to the damage award were thereby suggested via the multi-regression. The Back Propagation Neural Network was applied to construct the valuation model, wherein the 6 extracted factors were the inputs and the damage award was the output. The proposed valuation model was validated to have the predictive power by error analysis. It accommodated to valuate the possible damage award or to negotiate the settlement fee in disputing patent infringement lawsuits. It also contributed to patent transaction, patent licensing and hypothecation of intangible assets, etc.

【Keywords】patent valuation, factor analysis, back propagation neural network

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1. Introduction

As technologies develop rapidly and the era of knowledge economics arises, intangible assets show their higher significance than before. The patent stands for a leading role among various species of intangible assets. The patent contributes to enterprises by revenue, stock performance, reputation, research and development, so as to be an important factor for evaluating enterprises and nations in aspects of operation, management and innovation.

However, when considering the patent value, especially the monetary value, it is hard to valuate the patent because the patent is not only a kind of intangible assets, but also a kind of rights. When thinking about the asset, the financial experts usually concentrate their attention on patent's financial contribution. This contribution, such like stock performance or market success, is not directly generated by patents; it is only partly influenced by patents. When thinking about the right, the legal researchers always focus on the scope of patent right and related legal behaviors.

There exists an important phenomenon recently, that is, patent infringement lawsuits grow distinctly around the world. Damage award, licensing fee, and royalty become conspicuous parts of income, and even turn into the majority of revenue in some new start-up companies. No matter in negotiations of patent licensing, patent transaction, hypothecation of intangible assets, or shareholding by patent-based technologies, the monetary value of the patent is always a critical issue. Meanwhile, a reasonable and reliable patent valuation model is always discussed seriously for making patents become monetary assets. The issue of monetary valuation of patents is concerned by people including employees, chiefs, investors, researchers, and professionals among fields of technology management, financial operation, legal strategy, and business administration.

The existing patent valuation models in practice might be briefly summarized to three approaches (Reilly & Schweihs, 1998), such as the cost-based approach, the market-based approach, and the revenue-based approach. These approaches originated basically from the financial methods and then been modified.

The basic idea, on which the cost-based approach is based, is the idea of replacement. This means the value of a patent is identified as the amount that would be necessary to replace the protection right or the related economic benefit potential. The logic behind this approach is that a prospective buyer acting in a logical way would not be willing to pay more for a patent than the amount he would have to pay to obtain an equivalent protection right. The costs compared could be, for example, historical costs, costs of replacement or costs of reproduction, depending on the valuation method used. One advantage of the cost

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approach is that the evaluator of patents has little influence on the valuation result.

The market-based approach is based on a comparison with a corresponding transaction between independent third parties. That is, the value of a patent is defined through comparison to a similar patent, the market price of which is known through an earlier purchase or sale. In this market, there has to be a sufficient number of comparative transactions in the recent past, for which the obtained retail price is known. If this information exists, the market approach is easy to apply and leads to a valuation result that is acceptable and easy to comprehend. But the prerequisite of an active market is hardly met for patents. Furthermore, the published licensing rates are not sufficient for an adequate comparison.

The basis of the revenue-based approach is the comparison of the future economic benefit of a patent with the future benefit of an alternative investment. So far, the income approach implements the definition of value most directly. With the application of the income approach, the sum of advantages, i.e. the additional returns or saved costs less accruing costs, that will arise from the patent will be ascertained. These economic benefits are compared to the best alternative investment, which shows the same future payment flows and the same investment risk. With respect to the valuation, the comparison is made by determining the future economic benefit of the protection right and then discounting it with a risk-adapted interest rate to its actual cash value. To put it another way, the income approach answers the question: what sum would have to be invested in another way to achieve identical payment flows with the same risk? The valuation results would be somehow risky since the data employed are only prediction-based values and cannot be determined with certainty.

Unfortunately, the aforementioned financial approaches for patent valuation usually disregard the subject matter of the patent and species of enforcement defined and restricted by patent law. These existing patent valuation approaches are more likely named as the "Technology" valuation approaches. It has to be emphasized that a vital difference exists in the scope of right between a technology and a patent. The vital difference will result in different valuation outcome. The right of a technology is knowledge-based power to make, use, or sell; whereas the right of a patent is the power to exclude others from making, using, selling or importing.

Regarding the topics involved the patent law with the patent value, Lanjouw and Schankerman (1997) discussed patent owner's behaviors in patent litigation events. Lanjouw, Pakes, and Putnam (1998) used the cost of patent prosecution as the indicator to

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evaluate patents. Lanjouw (1998) discussed the behaviors in patent prosecution for evaluating patents. Lanjouw and Schankerman (2001) discussed the behaviors in patent infringement lawsuits for evaluating patents. Reitzig, Henkel, and Heath (2007) proposed that the patent infringement lawsuit affected the firm's strategies.

According to U.S. patent law 35U.S.C.154 "*Every patent shall contain a short title of the invention and a grant to the patentee, his heirs or assigns, of the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States, and, if the invention is a process, of the right to exclude others from using, offering for sale or selling throughout the United States, or importing into the United States, products made by that process, referring to the specification for the particulars thereof.*" the right of a patent for the patentee is definitely designated for excluding others from five species of unauthorized behaviors: making, using, offering for sale, selling and importing. Based on the concept of patent law, any patent which can not be enforced the right to exclude others from aforementioned five behaviors would be regarded as legally valueless. The existing patent valuation models in practice usually take this important legal issue aside.

As described above, it's therefore a principal objective of this study to rediscover the patent value in view of patent law by investigating patent infringement lawsuits because the documents of patent infringement lawsuits indicate patents and their momentous, direct and monetary patent values, i.e. damage awards.

It's another objective of this study to construct a monetary valuation model of patents by discussing the mathematical relationship between damage awards and patents.

2. Review of Literatures

Regarding the topic of patent valuation and patent indicators, Cockburn and Griliches (1988) first discussed the relationship between stock performance and patents. Albert, Avery, Narin, and McAllister (1991) applied the citation count as the indicator to evaluate patents. Tong and Frame (1994) used the patent claim as the indicator to evaluate national technology outcome. Hirschey and Richardson (2001) suggested that scientific measures of the quality of inventive output were useful indicators to investors. In this literature, the scientific measures of the quality meant the prior arts of non-patent references of patents. Hereof, Schererc, and Vopel (2003) suggested that the number of prior arts and citations received were related positively to the patent value; non-patent references were informative about the value of pharmaceutical and chemical patents, but not in other technical fields;

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patents, which were upheld in opposition and annulment procedures, and patents representing large worldwide patent families were particularly valuable. In this literature, backward citations, forward citations, non-patent references, and worldwide patent families were concluded to be positive to the values of the patent. Hirschey and Richardson (2004) found a favorable stock-price influence when both the number of patents, the scientific merit of these patents, and the R&D spending were high, where patent citation information could indeed help investors judge the future profit-earning potential of a firm's scientific discoveries. In this literature, backward citations, forward citation, and non-patent references were concluded to be positive to the stock-price. Reitzig (2004) inspected almost all the possible detailed patent indicators with the market value of the patent owner. He concluded that actions of the prosecution were positive to the market value of the patent owner. But legal values of patents in this literature were not considered. Hall, Jaffe, and Trajtenberg (2005) used the patent citation count as the indicator and discussed its contribution to market value. Von Wartburg, Teichert, and Rost (2005) proposed a methodological reflection and application of multi-stage patent citation analysis for the measurement of inventive progress. In this literature, backward citations and forward citations were concluded to be positive to R&D activities. Choy, Kim, and Park (2007) employed patent analysis in cross-impact analysis of syntheses and interactions between various technologies and expected to help practitioners to forecast future trends and to develop better R&D strategies. In this literature, influences of patents were thoroughly analyzed, but legal values of patents were ignored. Hereof and Hoisl (2007) described the characteristics of the German Employees' Inventions Act and discussed which incentives it created with a survey of 3,350 German inventors to test the hypotheses regarding this institution; and finally concluded that the law created substantial monetary rewards for productive inventors. In this literature, the patent law was watched and the law-related value of patents was discussed. Silverberg and Verspagenb (2007) focused on the analysis of size distributions of innovations by using patent citations as one indicator of innovation significance. In this literature, backward citations, forward citations, and non-patent references were concluded to be positive to innovations but legal values of patents were not discussed. Van Trieste and Vis (2007) focused on evaluating a patent on the basis of cost-reducing process improvements from the viewpoint of the patent-holding firm by considering the relevant cash flows that resulted from owning the patent, wherein the patent value was determined by licensing fees, royalty income, and the competitive advantage resulting from the patent and patent maintenance costs. In this literature, the law-related value of patents was first discussed, but no relationship was found

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between this law-related value and patent indicators. Chiu and Chen (2007) proposed an objective scoring system for patents from the licensor side using the Analytic Hierarchy Process to value patents for new products being developed by an actual enterprise. This scoring system was quite interesting; unfortunately, no monetary value was modeled.

The aforementioned literatures discussed lots of patent indicators and their contributions such like market success and stock performance. However, such contributions are not directly generated by patents, but they are influenced by patents. Besides, the aforementioned literatures somehow missed an important issue, that is, the patent is a right which given by law. It's more rational to discuss the patent value in view of patent law.

Regarding the topics involved the patent law, Lanjouw and Schankerman (1997) discussed patent owner's behaviors in patent litigation events. Lanjouw et al. (1998) used the cost of patent prosecution as the indicator to evaluate patents. Lanjouw (1998) discussed the behaviors in patent prosecution for evaluating patents. Lanjouw and Schankerman (2001) discussed the behaviors in patent infringement lawsuits for evaluating patents. Reitzig et al. (2007) proposed that the patent infringement lawsuit affected the firm's strategies.

Though these literatures discussed patents and indicators in view of patent law, there was no corresponding valuation model built yet.

Referring to the issue of a patent's monetary value, Deng, Lev, and Narin (1999), Thomas (2001) tried to use multi-regression to model patent indicators and the stock performance. Unfortunately, the R2 values were too low to explain few. Park and Park (2004) proposed a valuation method that generated monetary value, rather than a score or index, based on the structural relationship between technology factors and market factors. This method of generating the patent's monetary value was more useful in practice than the other indicator-based valuation models. Unfortunately, this method was not in view of patent law.

However, the mathematical relationship between the patent legal value and the aforementioned patent indicators has not been developed yet. A wide gap still exists between the patent and economics while considering the value of patents. In this study, a monetary valuation model for patent legal values is proposed to shorten the gap and link the patent and economics more directly.

3. Methodology

3.1 Population and Sample

This study focuses on the patent infringement lawsuits in U.S. district courts of Delaware, California and Texas. The patent law in U.S. is a federal law, actions for patent

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infringement filed in federal district courts. Either plaintiff or defendant can appeal to U.S. Court of Appeals for the Federal Circuit (CAFC) if either party does not agree with the judgment determination of district court. By studying a long time in this study, it is found that the lawsuit documents including patent damage award are usually disclosed, discussed, and determined in federal district courts, while only legal topics and questions of law are argued in CAFC. Hence, the patent lawsuits are retrieved through federal district courts in this study. U.S. patent lawsuits are filed in quantity in every federal district. For example, there is up to 2,865 patent related lawsuits from 1944 to 2006 in district court of Delaware, for each lawsuit possesses more than 5,000 documents of miscellaneous issues involved. In order to set up an effective way of modeling, this study only directs to three district courts those are famous in huge quantity and fast judgment of patent infringement lawsuits, i.e. district court of Delaware, district court of California, and district court of Texas. These courts have the accelerated timetable strictly adhered to deadlines, resulting in speedy disposition.

Effective samples for establishing valuation model are reviewed and extracted from all the retrieved patent related lawsuits by meeting all the following criteria:

(1) Lawsuit terminated to have the final judgment determination. Settled Lawsuits are excluded.

(2) Lawsuit disclosed definite patent numbers.

(3) Lawsuit indicated definite monetary value of damage award.

(4) The patent involved in a lawsuit possessed all well-defined patent indicators. If a patent infringement lawsuit is too old so that any one of the involved patents does not possess all well-defined patent indicators, such lawsuit should be excluded from effective samples.

Patent infringement lawsuits are retrieved in the period of 1944 to 2006 in both district courts of Delaware and California. But because district court of Texas is famous in showing favor to plaintiffs, lots of lawsuits get settlements, few lawsuits with final judgment of determination are found. Hence, patent infringement lawsuits of district court of Texas are retrieved from 1994 to 2006.

3.2 Delimitation and Limitation

There are several categories of U.S. patents, such as utility, design, plant, defensive publication, statutory invention registration, and additional improvement, etc. The compositions of all these categories differ from each other. This study discusses the utility

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patent only because the utility patent plays the major part of all U.S. patent categories. The infringement lawsuits of utility patents are much more than the others.

There is at least one patent included in a patent portfolio which is enforced in a patent infringement lawsuit to win a lump sum of the damage award. Only damage award of the portfolio is discussed. This study doesn't probe into the specific value of the specific patent in a portfolio.

Only patent infringement lawsuits with final judgment of determination are analyzed. Actually, settlements always exist to terminate patent infringement lawsuits because the defendant might want to reduce possible damage award of the plaintiff. In settled lawsuits, neither final judgment determination nor damage awards are found; such settled lawsuits should be excluded from effective samples.

Only quantitative patent indicators are analyzed. Qualitative patent indicators, such as patent quality and patent enforceability are excluded.

3.3 Instrumentation

The database for retrieving patent infringement lawsuits is the LexisNexis. The LexisNexis database originated since 1966 for being developed to the first full text retrieval system of legislation in the world by the American Air Force. It is one of the great law resources in the world, comprising legal documents, industry information, financial documents and public news of all levels of U.S. courts, newspapers, magazines and commercial periodicals.

Samples of lawsuits distribute in different years. The damage award of each lawsuit must be converted to a standard foothold to eliminate the currency revaluation and inflation for consistency of analysis. In this study, the annual interest announced by Federal Reserve System (FED) at the end of each fiscal year is used to convert each damage award to the corresponding value in 2006 by compound interest via engineering economic approach.

By Kolmogorov-Smirnov test, the values of damage awards of all lawsuits are converted by natural logarithm in order to have an approximate normal distribution.

For quantitatively describing properties of the patent, all related previous literatures are thoroughly studied. The quantitative properties of a specific patent, discussed in relevant previous studies were always focused on citations and patent family. Reitzig (2004) proposed a brand new indicator: actions of prosecution. Besides, based on the view point of patent law, throughout the opinion of court in patent infringement lawsuits in U.S., a product or a method infringes a patent claim if that product satisfies each of the claim requirements,

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hence what is claimed is recognized as the invisible boundary of a patent right. Besides, the fewer elements in a claim form a wider boundary, contrarily the more elements in a claim form a narrower boundary. In a patent, an independent claim usually comprises fewer elements, while a dependent claim certainly comprises more elements than the claim being dependent upon. Independent claims are more important than dependent claims, it's therefore not only the number of claims, but also the number of independent claims is considered in this study. International Patent Classification (IPC) and U.S. Patent Classification (USPC) are systems for organizing patents. A patent is designated its IPC and USPC by examiners in patent office. The number of IPC and USPC are considered in this study. In addition, according to the Manual for Patent Examining Procedure (MPEP), the claimed elements and characteristics thereof must be supported by descriptions and drawings, so the number of drawings is also considered. By reviewing previous studies and authors' empirical information and experiences of patent prosecution, patent search, and infringement analysis, there are 17 patent indicators finally summarized.

For constructing mathematical model, the more attributes or variables, the more information that probably results in the more complexity. It's the first time to describe patents by the large number of 17 quantitative indicators. A statistical data reduction technique called "Factor analysis" is then applied in this study for uncovering the latent data structure by identifying the groups of inter-related indicators to see how they are related to each other. By the tool of SPSS V8.0 with the extraction approach of Principal-Component-Method and Kaiser normalized Varimax rotation, 17 patent indicators are finally reduced to 9 extracted factors via factor analysis.

For discussing the linear relationship between the 9 extracted factors and the damage award, the multi-regression analysis is applied. In this study, the 9 extracted factors of each lawsuit are set to be the independent variables, while the damage award of each lawsuit is set to be the dependent variable. It shows that the relationship between the 9 extracted factors and the damage award is not linear because the R2 of the Regression model is too low. However, via the multi-regression analysis, 6 extracted factors which having higher influence to the damage award are suggested.

In order to model the nonlinear relationship between the extracted factors and the damage award, the Artificial Neural Network (ANN) is applied. The ANN is an information processing paradigm that is inspired by the way biological nervous systems. Learning in biological nervous systems involves adjustments to the synaptic connections that exist between the neurons. The key element of the ANN is the novel structure of the information processing

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system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. The ANN, like human, learns by examples, and is usually configured for some specific applications, such as pattern recognition or data classification. An important issue in ANN design is determining the number of hidden neurons best used in the network. If the hidden number of neurons is increased too much, overtraining will result in the network being unable to "generalize". The training set of data will be memorized, making the network effectively useless on new data sets. The Back Propagation Neural network (BPN), one of the most popular known neural networks learning technique, is applied in this study. The BPN looks for the minimum of an error function in weight space using the method of gradient descent. The combination of weights which minimizes the error function is considered to be a solution of the learning problem.

The ANN is widely applied in many fields, such as financial forecasting, human resource management and medical phenomena detection, etc. It is proved to be able to solve lots of nonlinear problems. However, the ANN has not been applied in dealing with the legal issues, especially the patent damage award. Hence, the first reason for applying the ANN in this study to modeling the nonlinear relationship between the extracted factors and the damage award is try to use an existed, popular and recognized tool for reducing the uncertainty during problem solving process.

The second reason for applying the ANN in this study to modeling the nonlinear relationship between the extracted factors and the damage award is that, the damage award in any patent infringement lawsuit was first proposed by both parties of plaintiff and defendant, then was discussed, argued, adjusted, negotiated, and finally determined by the judge or the jury of court. The process for determining the damage award is quite humanly and inexact. Therefore, the damage award resulted from its corresponding patents seems to be more preferably modeled by the ANN than the other equations having exact solutions.

The input variables for the BPN in this study are the 6 extracted factors having higher influence of each lawsuit, while the output variable is the damage award of each lawsuit. For constructing the BPN, basically at least two sets of samples are necessary, i.e. a training set and a testing set, for iteratively tuning the BPN by training and testing. Preferably, for validating the constructed BPN to check its predictive power, another validating set is introduced into the constructed BPN. Various parameters could be tuned in constructing the BPN. In this study, the convergence of Root-Mean-Squared-Error (RMSE) is observed when training, testing and validating the BPN, and therefore regarded as the performance index of the BPN.

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4. Analysis and Result

4.1 Effective Samples of Patent Infringement Lawsuits

By using the searching keyword "patent" in the LexisNexis database, 4,289 patent related lawsuits are searched from district courts of Delaware, California and Texas. However, not all of these lawsuits are infringement involved, further searching is needed. Thereby, the searching keyword selected from the group consisting of "damage" and "$" is then applied. The retrieved documents are carefully reviewed and checked by manpower; finally 65 effective samples (lawsuits) including 163 patents are derived, as shown in Table 1. There are 37 samples including 103 patents are in district court of Delaware; 24 samples including 52 patents are in district court of California; and 4 samples including 8 patents are in district court of Texas. In each of these effective samples, the damage award is clearly indicated, and the patent (s) involved has all 17 patent indicators. Once the infringement lawsuit in which patent involved is too old to be short of some patent indicators, the infringement lawsuit is then discarded.

Table 1 Samples retrieved and extracted from district courts of Delaware, California and Texas

Lawsuit resource		District court of Delaware	District court of California	District court of Texas	Sum
Lawsuits retrieved		2,865	1,314	110	4,289
Extracted lawsuits	Lawsuits	37	24	4	65
	Patents	103	52	8	163

Table 2 Patent infringement lawsuits in each year

Year	Lawsuits	Year	Lawsuits
2006	12	1997	2
2005	7	1996	0
2004	11	1995	1
2003	5	1994	0
2002	6	1993	0
2001	4	1992	1
2000	3	1991	2
1999	3	1990	0
1998	6	1989	2

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In the 65 effective samples, the portfolio size in a lawsuit varies from one patent to 17 patents; the damage award varies from USD 470,084 to USD 2,600,000,000. Table 2 shows the counts of infringement lawsuits from 1989 to 2006. Obviously, infringement lawsuits after 2000 are much more than those before 2000. Lawsuits with final determinations are only a small part of all infringement lawsuits. The information in Table 2 reveals that patent infringement lawsuit gradually becomes a kind of business in 21 century.

4.2 Patent Indicators

Based on the view point of patent law, throughout the opinion of court in patent infringement lawsuits in U.S., a product or a method infringes a patent claim if that product satisfies each of the claim requirements, hence what is claimed is recognized as the invisible boundary of a patent right. Besides, the fewer elements in a claim form a wider boundary, contrarily the more elements in a claim form a narrower boundary. In a patent, an independent claim usually comprises fewer elements, while a dependent claim certainly comprises more elements than the claim being dependent upon. Independent claims are more important than dependent claims, it's therefore not only the number of claims, but also the number of independent claims is considered in this study. International Patent Classification (IPC) and U.S. Patent Classification (USPC) are systems for organizing patents. A patent is designated its IPC and USPC by examiners in patent office. The number of IPC and USPC are considered in this study. In addition, according to the U.S. patent rule §1.75 (d) (1) "*The claim or claims must conform to the invention as set forth in the remainder of the specification and the terms and phrases used in the claims must find clear support or antecedent basis in the description so that the meaning of the terms in the claims may be ascertainable by reference to the description.*" the claimed elements and characteristics thereof must be supported by descriptions and drawings, so the number of drawings is also considered. By reviewing previous studies and authors' empirical information and experiences of patent prosecution, patent search and infringement analysis, there are 17 patent indicators finally summarized below and shown in Table 3.

X_1 named "Assignees" is the count of assignees in each patent.

X_2 named "Inventors" is the count of inventors in each patent.

X_3 named "Total claims" is the count of total claims in each patent.

X_4 named "Independent claims" is the count of independent claims in each patent. Total claims comprise independent claims and dependent claims. X_4 is a part, but the most important part, of X_3.

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X_5 named "US patent references" is the count of US patent documents listed in the field of "References Cited", i.e. prior arts recognized by the examiner, in each patent. Some literatures called "US patent references" as the "backward citations".

X_6 named "Foreign patent references" is the count of foreign patent documents in the field of "References Cited" in each patent.

X_7 named "Non-patent references" is the count of other publications (non-patent literatures, including papers, handbooks and magazines, etc.) in the field of "References Cited" in each patent. Some literatures called "Non-patent references" as the "science linkage".

Table 3 Patent indicators defined

Evaluation indicator		Definition	Mainly discussed by
X_1	Assignees	The assignee count of each patent	Reitzig (2004)
X_2	Inventors	The inventor count of each patent	Reitzig (2004)
X_3	Total claims	The total claim count of each patent	Reitzig (2004)
X_4	Independent claims	The independent claim count of each patent	Reitzig (2004)
X_5	US patent references	The count of US patent documents in the field of "References Cited" of each patent	Hereof et al. (2003) Hall et al. (2005) Von Wartburg et al. (2005) Silverberg and Verspagenb (2007)
X_6	Foreign patent references	The count of foreign patent documents in the field of "References Cited" of each patent	Hereof et al. (2003) Hall et al. (2005) Von Wartburg et al. (2005)
X_7	Non-patent references	The count of other publications in the field of "References Cited" of each patent	Hereof et al. (2003) Hirschey and Richardson (2004) Hall et al.(2005) Von Wartburg et al. (2005) Deng et al. (1999)
X_8	Forward citations	The count of follow-up citing patents in the beginning of sue of each patent	Hall et al. (2005) Von Wartburg et al. (2005)
X_9	International Patent Classifications (IPC)	The count of IPCs of each patent	*
X_{10}	US Patent Classifications	The count of USPCs of each patent	*
X_{11}	Worldwide patent family	Worldwide related patents claimed the same priorities of each patent (based on INPADOC database)	Hereof et al. (2003) Reitzig (2004)

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Evaluation indicator		Definition	Mainly discussed by
X_{12}	US patent family	US related patents claimed the same priorities of each patent (based on INPADOC database)	Hereof et al. (2003)
X_{13}	Office actions	The count of office opinions by the examiner of USPTO of each patent	Hereof et al. (2003) Reitzig (2004)
X_{14}	Responses	The count of responses to USPTO by the assignee of each patent	Reitzig (2004)
X_{15}	Examination	period from filing date to issue date of each patent	*
X_{16}	Drawing	The count of drawings of each patent	*
X_{17}	Life-span	Patent life-span from filing date to the beginning of suit	*

* proposed by this study

X_8 named "Forward citations" is the count of citations by the other patents in the beginning of lawsuit in each patent.

X_9 named "International Patent Classifications (IPC)" is the count of IPCs recognized by the examiner in each patent.

X_{10} named "US Patent Classifications "is the count of USPCs recognized by the examiner in each patent.

X_{11} named "Worldwide patent families" is the count of worldwide related patents those claimed at least one same priority in each patent. This count is investigated based on INPADOC database.

X_{12} named "US patent families" is the count of US related patents those claimed at least one same priority in each patent. This count is investigated based on INPADOC database.

X_{13} named "Office actions" is the count of office opinions by the examiner of USPTO in each patent. The office opinions include the selection by restriction, non-final rejection, final rejection, and notice of allowance, etc.

X_{14} named "Responses" is the count of responses to USPTO by the assignee in each patent. The responses include amendments, response to non-final rejection, response to final rejection, request for continued examination, and appear, etc.

X_{15} named "Examination" is the time span from filing date to issue date in each patent.

X_{16} named "Drawings" is the count of drawings in each patent.

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X_{17} named "Life-span" is the time span from filing date to the beginning of lawsuit in each patent.

4.3 Reducing Patent Indicators to Extracted Factors

In the factor analysis, KMO test is 0.537, while Bartlett's sphere test is 797, which is near Chi's distribution, so the 17 patent indicators are suitable for reduction to generate extracted factors. Table 4 shows the correlation matrix of the 17 patent indicators. Via the extraction approach of Principal-Component-Method and Kaiser normalized Varimax rotation, Table 5 shows the result of factor analysis, wherein, 9 extracted factors are extracted to provide the explanatory variation up to 82.89%. In these 9 extracted factors, F_7 comprises only one patent indicator X_{16}, F_8 comprises only one patent indicator X_1, F_9 comprises only one patent indicator X_2, so F_7, F_8 and F_9 are "patent indicators" indeed. However, for the consistency of denomination, F_7, F_8 and F_9 are still called "extracted factors" hereinafter in this study. The combination equations of patent indicators for each extracted factor are shown in Table 6. The 9 extracted factors with their nomenclatures and patent indicators are shown in Table 7.

F_1 denominated as "Strength of portfolio", consists of X_{11} (Worldwide patent families) and X_{12} (US patent families).

F_2 denominated as "Complexity of prosecution", consists of X_{15} (examination), X_{13} (Office actions) and X_{14} (Responses), The higher number of these indicators means the higher interactions between the patent office and the patent assignee, results in high complexity of prosecution.

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Table 4 Correlation matrix of 17 patent indicators

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	1.000	-0.139	0.111	0.082	-0.110	-0.242	0.045	0.032	0.084	-0.010	0.071	0.029	0.135	0.112	0.033	-0.040	0.071
X_2	-0.139	1.000	-0.008	-0.052	0.027	0.052	-0.040	-0.008	-0.075	-0.055	-0.053	-0.068	0.002	0.041	-0.095	0.201	0.070
X_3	0.111	-0.008	1.000	0.370	0.244	0.118	0.007	0.070	-0.064	-0.041	0.386	0.315	0.023	0.040	-0.050	0.123	-0.111
X_4	0.082	-0.052	0.370	1.000	-0.036	-0.140	0.008	0.209	-0.085	-0.098	-0.047	-0.085	0.108	-0.028	0.118	0.112	0.018
X_5	-0.110	0.027	0.244	-0.036	1.000	0.750	0.224	0.014	-0.035	-0.020	0.444	0.469	0.076	0.166	0.075	0.216	-0.285
X_6	-0.242	0.052	0.118	-0.140	0.750	1.000	0.280	-0.041	0.112	0.028	0.317	0.310	0.055	0.127	0.111	0.117	-0.223
X_7	0.045	-0.040	0.007	0.008	0.224	0.280	1.000	0.030	0.236	0.081	0.037	0.001	-0.014	0.063	0.064	0.051	-0.205
X_8	0.032	-0.008	0.070	0.209	0.014	-0.041	0.030	1.000	-0.121	0.238	0.161	0.158	0.111	0.043	-0.018	0.068	0.509
X_9	0.084	-0.075	-0.064	-0.085	-0.035	0.112	0.236	-0.121	1.000	0.485	-0.035	-0.052	0.159	0.300	0.164	-0.106	-0.046
X_{10}	-0.010	-0.055	-0.041	-0.098	-0.020	0.028	0.081	0.238	0.485	1.000	0.022	0.069	0.345	0.371	0.278	-0.148	0.123
X_{11}	0.071	-0.053	0.386	-0.047	0.444	0.317	0.037	0.161	-0.035	0.022	1.000	0.937	0.192	0.215	0.005	0.190	-0.169
X_{12}	0.029	-0.068	0.315	-0.085	0.469	0.310	0.001	0.158	-0.052	0.069	0.937	1.000	0.123	0.202	0.029	0.148	-0.178
X_{13}	0.135	0.002	0.023	0.108	0.076	0.055	-0.014	0.111	0.159	0.345	0.192	0.123	1.000	0.761	0.350	0.000	-0.001
X_{14}	0.112	0.041	0.040	-0.028	0.166	0.127	0.063	0.043	0.300	0.371	0.215	0.202	0.761	1.000	0.290	0.000	-0.168
X_{15}	0.033	-0.095	-0.050	0.118	0.075	0.111	0.064	-0.018	0.164	0.278	0.005	0.029	0.350	0.290	1.000	-0.140	0.045
X_{16}	-0.040	0.201	0.123	0.112	0.216	0.117	0.051	0.068	-0.106	-0.148	0.190	0.148	0.000	0.000	-0.140	1.000	-0.141
X_{17}	0.071	0.070	-0.111	0.018	-0.285	-0.223	-0.205	0.509	-0.046	0.123	-0.169	-0.178	-0.001	-0.168	0.045	-0.141	1.000

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Table 5 17 Patent indicators vs. 9 extracted factors by factor analysis

	F_1	F_2	F_3	F_4	F_5	F_6	$F_7(X_{16})$	$F_8(X_1)$	$F_9(X_2)$
X_2	-0.090	0.024	0.047	0.042	-0.039	-0.023	0.15	-0.054	0.936
X_1	0.069	0.107	-0.125	0.032	-0.011	0.061	-0.062	0.929	-0.047
X_9	-0.074	0.107	0.086	-0.140	0.860	-0.032	-0.070	0.091	-0.076
X_{10}	0.068	0.330	-0.036	0.263	0.748	-0.057	-0.115	-0.150	-0.047
X_5	0.426	0.096	0.753	-0.093	-0.113	0.055	0.044	-0.122	0.070
X_6	0.263	0.052	0.821	-0.091	0.024	-0.056	-0.059	-0.232	0.110
X_7	-0.193	-0.076	0.664	0.014	0.313	0.011	0.244	0.309	-0.180
X_3	0.444	-0.104	0.044	-0.083	0.057	0.759	-0.038	0.093	0.143
X_4	-0.179	0.120	-0.036	0.127	-0.121	0.861	0.123	0.068	-0.132
X_{16}	0.101	0.042	0.110	-0.086	-0.139	0.105	0.831	-0.065	0.134
X_8	0.145	0.057	0.026	0.888	0.036	0.121	0.177	-0.011	-0.087
X_{17}	-0.138	-0.069	-0.197	0.816	-0.020	-0.062	-0.24	0.058	0.157
X_{11}	0.921	0.107	0.162	0.020	-0.016	0.056	0.101	0.064	-0.044
X_{12}	0.927	0.087	0.161	0.027	-0.015	-0.028	0.054	-0.063	-0.073
X_{13}	0.098	0.900	-0.041	0.043	0.104	0.033	0.048	0.070	0.019
X_{14}	0.175	0.832	0.027	-0.103	0.267	-0.049	0.086	0.077	0.075
X_{15}	-0.143	0.586	0.249	0.060	0.059	0.129	-0.44	-0.049	-0.138

F_3 denominated as "Strength of patentability", consists of X_5 (US patent references), X_6 (Foreign patent references) and X_7 (Non-patent references). These indicators represent the related prior arts. The most important two criteria for examining patents in the patent office are the novelty, which is according to patent law 35 U.S.C. 102 (a), (b), (c), (d), (e), (f), (g), and unobviousness, which is according to patent law 35 U.S.C. 103 (a), (b), (C). That is, the claimed characteristics of any invention should not be disclosed in any one of the prior arts, and should not be the simple combination of some or all prior arts. In point of examination, the more prior arts for a granted patent, the stronger novelty and unobviousness.

F_4 denominated as "Influence of timing", consists of X_8 (Forward citations) and X_{17} (Life-span). As time goes, the number of following citations to a patent usually grows accordingly. The life-span from the patent filing date to the beginning of suit contributes the influence of timing.

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F_5 denominated as "Scope of technology", consists of X_9 (IPC) and X_{10} (USPC). Both IPC and USPC are systems for organizing patents. A patent is designated its IPC and USPC by examiners in patent office. The count of IPC and USPC indicates the species or technologies involved.

F_6 denominated as "strength of right", consists of X_3 (Total claims) and X_4 (Independent claims). Throughout patent infringement lawsuits in U.S., what is claimed is recognized as the invisible boundary of a patent right.

F_7 denominated as "Level of concrete", consists of only one indicator X_{16} (Drawing). Though the boundary of right is formed by the literalness of claim, it's also true that the more drawings make the patented invention more clearly and easily being understood either in examining a patent by examiners or studying a patent by the publics.

F_8 denominated as "Level of ownership sharing", consists of only one indicator X_1 (Assignees). All of assignees share the right of a patent. When enforcing the right of patent, such as filing a lawsuit or licensing, it's necessary to get the agreement which is subscribed by all of assignees.

Table 6 Extracted factors and combination equations

Extracted factor	Combination equation
F_1	$0.921\ X_{11} + 0.927\ X_{12}$
F_2	$0.586\ X_{15} + 0.900\ X_{13} + 0.832\ X_{14}$
F_3	$0.753\ X_5 + 0.821\ X_6 + 0.664\ X_7$
F_4	$0.816\ X_{17} + 0.888\ X_8$
F_5	$0.860\ X_9 + 0.748\ X_{10}$
F_6	$0.759\ X_3 + 0.861\ X_4$
F_7	$0.831\ X_{16}$
F_8	$0.929\ X_1$
F_9	$0.936\ X_2$

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Table 7 Nomenclature of 9 extracted factors

Extracted factor	Nomenclature	Patent indicators included	
F_1	Strength of portfolio	X_{11}	Worldwide patent families
		X_{12}	US patent families
F_2	Complexity of prosecution	X_{15}	Examination
		X_{13}	Office actions
		X_{14}	Responses
F_3	Strength of patentability	X_5	US patent references
		X_6	Foreign patent references
		X_7	Non-patent references
F_4	Influence of timing	X_8	Forward citations
		X_{17}	Life-span
F_5	Scope of technology	X_9	International Patent Classifications (IPC)
		X_{10}	US Patent Classifications (USPC)
F_6	Strength of right	X_3	Total claims
		X_4	Independent claims
F_7	Level of concrete	X_{16}	Drawings
F_8	Level of ownership sharing	X_1	Assignees
F_9	Strength of innovation	X_2	Inventors

F_9 denominated as "Strength of innovation", consists of only one indicator X_2 (Inventors). According to the patent law, each inventor of a patent must contribute some invented characteristics; the inappropriate one should be expelled from the inventor list. The more appropriate inventors form a stronger term of innovation for study and development.

For generating the portfolio-based extracted factors, each patent is analyzed to find out the values of its individual 9 extracted factors, each value of the portfolio-based extracted factor is then derived by the summation of the values of all specific patents included in each lawsuit.

4.4 Multi-Regression Analysis

In Multi-Regression Analysis, if the coefficient of determination R^2 value approximates to 1, then the error of the regression model is small and the linear relationship for each indicator corresponding to the damage award is easily explained.

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Before the multi-regression analysis, the descriptive statistics of the averages and the standard deviations of the 9 extracted factors and the damage award are performed as shown in Table 8. Because these variables F_1 to F_9 do not have the same unit for counting, the averages and the standard deviations of all these variables differ critically. The high variances exist.

Table 8 Descriptive statistics of each extracted factors and damage award

Extracted factor	Nomenclature	Average	Standard deviation
F_1	Strength of portfolio	128.8184	255.5860
F_2	Complexity of prosecution	14.7075	12.7851
F_3	Strength of innovation	65.1252	95.4796
F_4	Influence of timing	54.6517	69.9209
F_5	Scope of technology	9.9207	7.9300
F_6	Strength of right	57.7555	60.1863
F_7	Level of concrete	13.2193	15.1242
F_8	Level of ownership sharing	2.2296	1.6074
F_9	Strength of inventing team	4.9248	4.3598
Damage award		16.2315	1.9493

In Table 8, F_1 (Strength of portfolio), F_3 (Strength of innovation), F_4 (Influence of timing) and F_6 (Strength of right) have higher averages and standard deviations than the others.

The high variances of all these variables F1 to F_9 will ruin the multi-regression model. In order to improve the consistency of analysis, normalization of all the 9 independent variables (F_1 to F_9) is necessary. It is therefore to make the 9 independent variables being transformed to the Z-scores before the multi-regression analysis.

Via the tool of SPSS V8.0, the multi-regression equation for modeling the dependent variable (damage award) with the 9 independent variables (F_1 to F_9) is formed. The regression coefficients for each independent variable are shown in Table 9, while the derived R^2 value is 0.305 and the adjusted R^2 value is 0.192.

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Table 9 Regresssion coefficients of the nine normalized independent variables

Variable and nomenclature		Regression coefficient
Constant term		16.231
F_1	Strength of portfolio	-0.519
F_2	Complexity of prosecution	0.747
F_3	Strength of innovation	0.213
F_4	Influence of timing	1.111
F_5	Scope of technology	-0.494
F_6	Strength of right	0.270
F_7	Level of concrete	-0.189
F_8	Level of ownership sharing	-1.028
F_9	Strength of inventing team	0.461

Either the R^2 value or the adjusted R^2 value in this multi-regression analysis is too low to have enough explanatory ability. However, it's still interesting to have interesting findings, wherein some echo the previous literatures but some are contrary to the observations proposed before.

There are five positive variables which positively contribute to the damage ward and four negative variables which negatively affect the damage award. The positive ones are F_2 (Complexity of prosecution), F_3 (Strength of innovation), F_4 (Influence of timing), F_6 (Strength of right), and F_9 (Strength of inventing team). The negative ones are F_1 (Strength of portfolio), F_5 (Scope of technology), F_7 (Level of concrete), and F_8 (Level of ownership sharing).

This result shows some different findings from the conclusions proposed by previous literatures.

Reitzig (2004) concluded that the assignee's actions contributed the patent values. F_2 (Complexity of prosecution) gets the value 0.747 and echoes. Hirschey and Richardson (2001), Hereof et al. (2003), Hirschey and Richardson (2004), Von Wartburg et al. (2005), and Silverberg and Verspagenb (2007) proposed that citations which including backward and forward citations, or non-patent references contribute the value of patents. In Table 9, though F_3 (Strength of innovation) gets the positive value 0.213 to have the positive contribution to the damage award, but it's the lowest one among all positive values, wherein F_3 (Strength of innovation) consists of non-patent references and backward citations which including US patent references and Foreign patent references. It means that F_2 (Complexity of prosecution), F_4 (Influence of timing), F_6 (Strength of right), and F_9 (Strength of

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inventing team) contribute more than F_3 (Strength of innovation) to the damage award.

F_4 gets the highest positive value 1.111 to have the most contribution to the damage award. Since F_4 (Influence of timing) consists of patent life-span and forward citation, it is found in this study that not only forward citation but also patent life-span strongly contributes the damage award. Additionally, Hereof et al. (2003) suggested that worldwide patent families were positive to patent values, but F_1 (Strength of portfolio) gets the negative value -0.519 to show its negative affection to the damage award, wherein F_1 consists of worldwide patent family and US patent family.

The abovementioned comparisons are summarized in Table 10, wherein "CDA" means "contribution to the damage award found in this study", "CVP" means "contribution to patent values proposed in previous literatures", the symbol "+" means "positive contribution", "N/A" means "not available or not significant in previous literatures", the symbol "-" means "negative contribution", the more symbols mean more contributions.

By multi-regression analysis, it tells a fact that the relationship between the damage award and the 9 extracted factors is hard to be modeled as a linear combination. However, it is still found that there are 6 extracted factors which having higher regression coefficients, i.e. F_1 (-0.519) F_2 (0.747), F_4 (1.111), F_5 (-0.494), F_8 (-1.028) and F_9 (0.461); and there are 3 extracted factors which having lower regression coefficients, such as F_3 (0.213), F_6 (0.270) and F_7 (-0.189). The extracted factors having higher regression coefficients show their higher influence to the damage award than those extracted factors having lower regression coefficients.

Table 10 Contributions of extracted factors

Extracted factor	Nomenclature	CDA	CPV
F_1	Strength of portfolio	-	+++(Hereof et al., 2003)
F_2	Complexity of prosecution	+ +	++ (Reitzig, 2004)
F_3	Strength of innovation	+	+++ (Hirschey & Richardson, 2001) +++(Hereof et al., 2003) +++ (Hirschey & Richardson, 2004) +++ (Von Wartburg et al., 2005) +++ (Silverberg & Verspagenb, 2007)
F_4	Influence of timing	+ + +	+++ (Hirschey & Richardson, 2001) +++ (Hereof et al., 2003) +++ (Hirschey & Richardson, 2004) +++ (Von Wartburg et al., 2005) +++ (Silverberg & Verspagenb, 2007)

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Extracted factor	Nomenclature	CDA	CPV
F_5	Scope of technology	--	N/A
F_6	Strength of right	+	N/A
F_7	Level of concrete	-	N/A
F_8	Level of ownership sharing	- - -	N/A
F_9	Strength of inventing team	++	N/A

4.5 Back Propagation Neural Network Modelling

The input variables for the BPN in this study are 6 extracted factors which having higher regression coefficients, i.e. F_1 (-0.519) F_2 (0.747), F_4 (1.111), F_5 (-0.494), F_8 (-1.028) and F_9 (0.461) as shown in Table 8; while the output variable is the damage award. Other extracted factors which having lower regression coefficients, such as F_3 (0.213), F_6 (0.270) and F_7 (-0.189), are discarded because of their lower influence to the damage award. Meanwhile, the input variables are normalized to z-scores to be within the interval of 2 standard deviations for eliminating the affection of some abnormal values; while the output variable is scaled to 0.2 to 0.8.

Since there are 65 effective samples as shown in Table 1, wherein the 53 samples from 1989 to 2005 are chosen to be the training set and the testing set for constructing the BPN, and the 12 samples in 2006 are chosen to be the validating set for validating the predictive power of the BPN. Moreover, 35 samples are randomly selected from the 53 samples to be the training set and the other 18 samples left are the testing set.

By manual and iterative process of trial and error to find the optimal settings of all parameters of the BPN and to observe the RMSE plots and values of convergence, the optimal model is derived. Figure 1 shows the convergence plot of RMSE versus learning cycle of the optimal model, wherein the vertical axis represents the scaled RMSE; the horizontal axis represents the learning cycle; the lower line represent RMSE of the training set; the upper line represents RMSE of the testing set.

In Figure 1, RMSE of the training set converges to 0.059 (5.9%); while RMSE of the testing set converges to an acceptable value 0.107 (10.7%). Though these values of RMSE are not perfect, they are still acceptably reasonable.

In the above-constructed BPN, some optimal parameters used are shown below:

Number of neurons in the first hidden layers: 6

Number of neurons in the second hidden layers: 0

Sampling approach for the training set and testing set: random

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Margin for weightings for interconnections: -0.5 to 0.5

Learning cycles: 4,000

Testing cycles: 40

Learning type: batched learning

Initial value of the learning speed: 1.0

Decreasing rate of the learning speed: 0.99

Initial value of the inertia: 1.0

Decreasing rate of the inertia: 0.99

For validating the evaluation model, the validating set composed of 12 samples in 2006 is then introduced into the constructed BPN to see its RMSE value and check the predictive power of the constructed BPN. Table 11 shows the comparison of RMSE values of the training set, the testing set and the validating set.

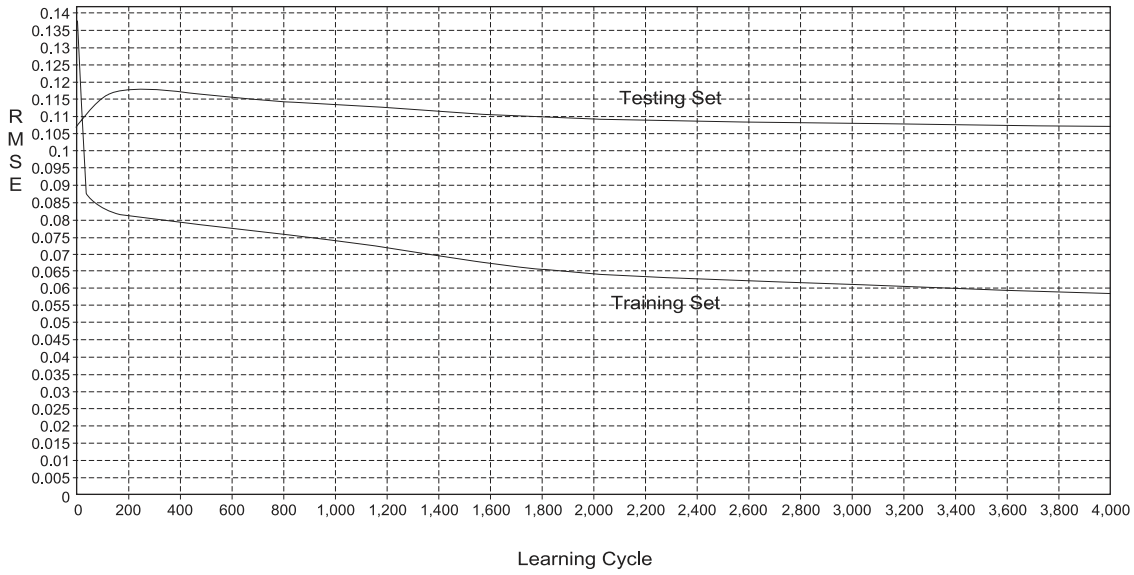


Figure 1 RMSE convergence vs. learning cycle

After validation, RMSE 0.106 (10.6%) of the validating set is derived. Though RMSE 0.106 (10.6%) of the validating set is a little higher than RMSE 0.059 (5.9%) of the training set, it is still superior to RMSE 0.107 (10.7%) of the testing set, hence the validation is successful. The successful validation means that the valuation model of the BPN constructed by samples from 1989 to 2005 can predict for samples in 2006. Though the relationship between the damage awards and the extracted factors is nonlinear, the nonlinear relationship

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still can be modeled by the BPN with an acceptable error. It proves that the proposed BPN gets the predictive power and the valuation model is feasible. Once the 6 extracted factors of a patent or a patent portfolio are inputted into the BPN valuation model, a possible damage award with an estimated error is outputted.

Table 11 The comparison of RMSE values of the training set, the testing set and the validating set

	Number of samples	RMSE
The training set	35	0.059
The testing set	18	0.107
The validating set	12	0.106

5. Discussion and Recommendation

This study combining the knowledge of legal, financial, computational and managerial experts provides a brand new concept for analyzing the patent infringement lawsuits so as to propose a monetary valuation model of patents. However, this study does not claim an unbeatable methodology to solve the damage award neither in all kinds of patent infringement lawsuits nor in all U.S. district courts. This study would like to show that the patent infringement lawsuits are not only good for case study but also good for quantitative analysis.

In this study, 17 patent indicators are summarized and proposed for quantitatively describing patents. By way of factor analysis, 9 extracted factors possessed of the explanatory variation up to 82.89% are derived. The 9 extracted factors describe quantitative dimensions of patents more concisely than the raw 17 patent indicators.

The linear relationship between the damage award and these proposed 9 extracted factors is discussed by multi-regression analysis. Because the R^2 value is low, it shows that the damage award is not linearly proportional to any one of the 9 extracted factors.

Furthermore, though lots of previous literatures proposed that citations which including backward and forward citations, or non-patent references contribute the revenue, stock performance, or investor's confidence, but in this study, these citations do not show such similar contributions to the patent legal values "damage awards" in patent infringement lawsuits. Via the multi-regression analysis, it is found that among all kinds of citations, only forward citation strongly contributes the damage award, the other citations contribute the damage award less. More particularly, patent life-span shows the similar contribution as the

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forward citation. Besides, patent families do not contribute but negatively affect the damage award. Patent applicant should seriously consider the strategy of filing patent families, because patent families cost lots of money. These findings directly help in managing the strategy of the patent applications. Via the multi-regression analysis, it is also found 6 extracted factors which having higher influence to the damage award.

Though the relationship between the damage award and the extracted factors is nonlinear, the relationship is successfully modeled by the BPN. The BPN is constructed by 53 samples from 1989 to 2005 and is validated by 12 samples in 2006. By RMSE analysis, the BPN shows its predictive power and is proved to be feasible.

However, it has to be emphasized to be careful when constructing the patent valuation model via the BPN. There are lots of parameters could be set and adjusted of the BPN. Though the BPN can "learn by itself", the manual and iterative process of trial and error is still needed to find the optimal settings of all parameters by observing the RMSE plots and values of convergence. Meanwhile, the learn cycles need to be cautiously check for preventing the phenomenon of "over-learning".

Figure 2 shows the architecture of the patent valuation model proposed by this study. For the application in practice, please see the bold lines in Figure 2, once the 17 indicators of a patent or a patent portfolio are described to be inputted in the valuation model, the 9 extracted factors are then generated by the combination equations. The 6 extracted factors which having higher influence are set to be the input variables of the BPN, consequently an output variable is generated to be the possible value of damage award if the patent or the patent portfolio being disputed in the infringement lawsuit. Referring to the dotted lines in Figure 2, the BPN would be certainly improved by feeding more samples of patent infringement lawsuits, such as the lawsuits from the district courts other than Delaware, California and Texas, so as to refine the patent valuation model. More particularly, because the timing issue is already considered in the patent indicators (X_8 and X_{17}) and currency-converted damage awards, as years go by and recent samples are fed, the valuation model learns to adjust itself dynamically. A single patent or a patent portfolio via this model can be valuated to distinct values at different time of valuation. It makes sense to make the valuation model to fulfill the reality. It's a living and growing valuation model for providing the monetary legal values of patents.

The proposed patent valuation model will accommodate to disputing patent infringement lawsuits. Both parties, either the plaintiff or the defendant, can use the proposed model in valuating the possible damage award so as to draw up the lawsuit

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strategies. The proposed patent valuation model will also help in negotiating the lawsuit settlement fee or the patent licensing fee. It also works for any company in assessing its patent assets, to see the value of patent assets higher than, lower than or similar to those patents won damage awards. The assessment result will be a reliable reference for the decision of keeping patents alive, drop patents without paying maintenance fee, patent donation or patent auction, so as to help patent management. It contributes to patent transaction, hypothecation of intangible assets, and shareholding by patent-based technologies, etc.

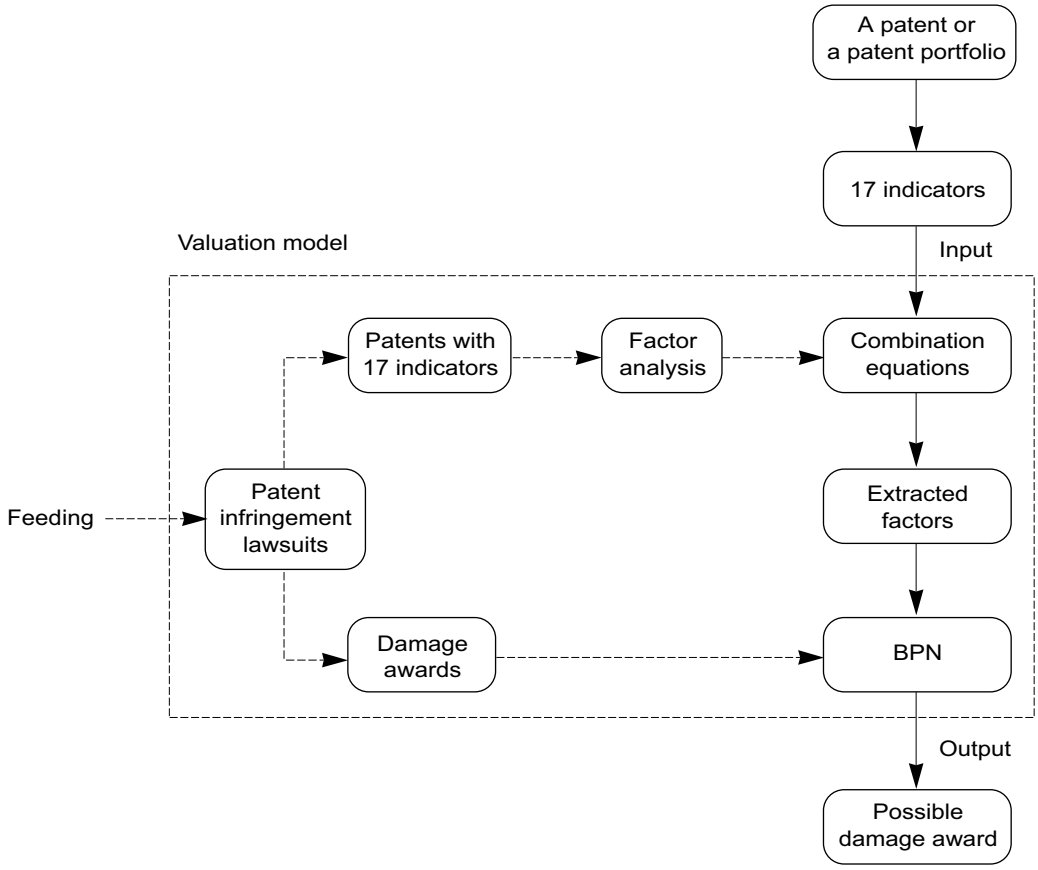


Figure 2 The architecture of the proposed patent valuation model

It also recommended that some topics might be suitable for further studies:

(1) Variance analysis: It is believed that the proposed valuation model may accommodate to patents in various industries, various technologies, and even various

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countries. Before this, variance analysis is necessary for appropriately adjusting raw patent indicators, extracted factors and optimal parameter settings of the BPN.

(2) Optimal design for patent compositions: For maximizing the possible damage award, it would be possible by setting the damage as the object function while patent indicators as independent variables, so as to get an optimal solution for patent compositions. This result would be great helpful to manage R&D outcome and innovation activities.

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