Study on Indicator System for Core Patent Documents Evaluation

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Abstract
Patent literatures are important evidence for technology assessment and forecasting activities. Previous researches suggest that the mean value of patent rights is low while there are only a few core patents playing the key roles in technology development. Hence core patent documents evaluation makes significant sense in technology assessment and forecasting. This paper proposes an objective scoring system for core patent documents evaluation, wherein most of the employed indicators are available from the publicly published patent data bank so that the operation of the evaluating activity is feasible. The AHP and Delphi Questionnaire interviews are conducted in our research, with a group decision-making model based on the Maximum Likelihood and Unbiased Estimation theory introduced.

Introduction
Patent literatures are major records of the outputs of technology innovation, having long been recognized as an important data resource for technology assessment and forecasting activities. According to the revealing by WIPO, over 90% of all the world's inventions could be found in patent documents. However, among these mass documents there are only a few core patents playing key roles in technology development. Existing researches examined the distribution of the value of patent rights, suggesting that the mean value of patent rights is so low for that only 5% to 10% patents aggregate the half of the gross value (Schankerman, 1986). Since only a small proportion of patents turn out to be of extraordinary value in the long run, identifying these core patents is significant for technology assessment and forecasting.

There is not any exact definition about core patent till now. It is a relative conception to the "periphery patent". Generally, the patents which are too essential to avoid in a technology field are called core patents in this field. Sometimes they are called basic patents. They are the seeds of technology innovation, which have high patent value.
Some researches have tried to determine patent value, some of which have constructed indicator systems to evaluate patent qualities. However most of these evaluate models are on the level of looking into the capabilities of players such as corporations, institutions and even countries. In addition, the indicators wherein include more market and economic elements. Patent valuation is especially challenging primarily because of the great uncertainty affecting their returns and for the lack of market-based data, which are far beyond the public data so that they are too difficult to operate.

This study aims to construct an indicator model for identifying core patent documents of a certain technology field in patent information analysis. Using the AHP and Delphi Questionaire, we propose an objective scoring system of multiple dimensions. For the feasibility of operation, in our model system, most of the employed indicators can be drawn from publicly available patent data banks, which makes the gauge activity easier to operate.

This paper is organized as following. In Section 2, we discompose the evaluating goal into effective dimensions and criteria, and lay out the indicators basing on the literature investigation. The methodology framework is provided in Section 3, including AHP, Delphi

Proceedings of ISSI 2009, pages 154–164.
Edited by B. Larsen and J. Leta.

Questionnaires and Group Decision-making. Section 4 presents the research results of the evaluation hierarchical structure and the weighting values. Finally, conclusions and future research design are presented in Section 5.

Indicators

The most fundamental and challenging task is to select suitable indicators. There are already a variety of variables which have been tested as indicators of patent value in pioneering work. Reitzig proposes 13 best-known indicators for business purposes, including Market value of corporation (Reitzig, 2002). Then these indicators are enlarged in his following research (Reitzig, 2004). Li etc. review patent value indicators and comb their structures (Li, 2007). Chiu provides a patent-scoring system from licensor side, which is applied to value the patents for new products being developed by an actual enterprise (Chiu, 2007).

However, most of these researches structure the knowledge on the evaluation of patent rights from a corporate perspective. They focus on the assessment of utilities' intangible assets or innovation capabilities. Besides, some indicators concerning market value, product price or cost are not easy to access. There is a lack of scientific papers that restructure a core patent document scoring system and the employed indicators are based on public patent literatures or databases.

In this study, basing on the public patent literatures, we value core patent documents in three main dimensions: technology, market and legal. Main attributes and their relationships are drawn and analyzed. By expert interviews and questionnaires, we select our indicators as bellowing.

Technology Attribute

We use four criteria to assess this attribute: Technology Scope (TS), Technology Impact (TI), Science Strength (SS), and Standardization Activity (STA). For each criterion, there are several indicators.

1. Number of IPC

Each patent document is assigned by the patent examiner to 9-digit categories of the International Patent Classification (IPC) system. The IPC is a technology-based classification system and patents may be assigned to more than one sub-class. In examining the impact of patent scope on firm value, Liner develops a proxy based on the IPC scheme (Lerner, 1994). He is successful to measure the 'breadth' or 'scope' of a patent by the average number of four-digit IPC.

This indicator is employed in this paper to measure the technology scope of the given document by discovering the diversity of technology classes into which the patent document falls.

2. Number of Claims (CLN)

A patent is comprised of a set of claims which delineate the boundaries of the property rights. The claims define the essential novel features of the invention in their broadest form and describe detailed features of the innovation claimed. The patentee has an incentive to claim as much as possible in the application, but the patent examiner may require that the claims be narrowed before granting.

The number of claims in a patent document is regarded as an indicator of national technological capacity (Tong, 1994). The relationship between claims and value is supported by the fact that claims are positively correlated with forward and backward citation in all technology areas (Lanjouw and Schankerman, 1999). And in 2000, it was argued that litigated patents have both more claims and more valuable claims, and the number of claims is employed to measure the technological breadth of the patent (Lanjouw and Schankerman, 2001).

3. Technology Dependence (TD)

Since Ellis introduced the citation network to display the history of technological subjects and their key turning points in 1978 (Ellis, 1978), the patent citation is regarded as a validate indicator of patent value in numerous subsequent surveys, including the forward citations and the backward citations (Trajtenberg, 1990) (Albert, 1991) (Narin, 1997) (Lanjouw and Schankerman, 2001) (Harhoff and Reitzig, 2002) (Harhoff, 2003) (Gay, 2005) (Haupt, 2007).
The "Technology Dependence" indicator here is derived from cited frequency. In general, the earlier the patent document is published, the more frequently it is cited. In order to avoid the interference by the patent age, the relative level to the average of the same age patents is introduced here. Thus the Technology Dependence of the *k*th patent document in a subject is measured as

$$TD_k = \frac{OCT_k / CT_k}{\sum OCT_n / \sum CT_n}$$

Wherein OCT_k means the other-cited times to the *k*th patent, CT_k means the gross cited times to it, *n* means the number of the same-age patents in this given subject.

4. Technology Cycle Time (TCT)

The TCT is the average age of the patents cited on the front page of a patent document. It is a measure for technological progress. The measure assumes that the more recent the cited patents are, the more quickly one generation of inventions is replacing another. It indicates speed of innovation or how fast the technology is turning over (Kurtossy, 2004). CHI uses the median rather than the average age of the cited references because there are, very often, one or two old classic references used in a patent, and if the average is used these one or two very old references would distort the data (Narin, 1995) (Thomas, 2001).
In this study, TCT is the median age of the patent citations of a given patent document. Technology recorded in the document with shorter cycle times than others is regarded as advancing more quickly from prior technology to current technology. TCT is employed to identify documents that may gain advantage by innovating more quickly.

5. Science Linkage (SL)

SL measures whether a company's technology builds upon cutting-edge scientific research. It is based on the average number of references to scientific papers instead of to previous patents, for a company's patents. According to CHI, companies whose patents cite a large number of scientific papers appear to be working closely with the latest scientific developments and at the technology forefront than their competitors (Narin, 1995) (Thomas, 2001) (Kurtossy, 2004).
Here, SL is adjusted as an indicator of how closely the technology in the given patent document is linked to forefront scientific research. It is evaluated as the quantitative ratio of the non-patent citations of a given patent document to the average level of the same age patents, as following:

$$SL = \frac{NSC_k}{\sum NSC_n / n}$$

Wherein NSC_k means the number of the scientific citations of the *k*th patent document, *n* means the number of the same-age patent documents in this given subject.

6. Science Cycle Time (SCT)
Referring to the TCT indicator, Science Cycle Time is created. SCT is the mean age of the scientific citations on the front page of a given patent document. It indicates the strength of scientific linkage between this document and the science research.

7. Science Impact (SI)
This indicator is created here by referring the Journal Impact Factor. Journal Impact Factor is a quantitative tool for evaluating journals, and a measure of the frequency with which the "average article" in a journal has been cited in a given period of time. By investigating the impact of these Journals which are the sources of the scientific references, SI index discovers the significance of the scientific research foundation of a given patent document. The *k*th patent document's SI value is calculated as

$$SI_k = \sum_{j=1}^{m} (NSC_j \times IF_j)$$

Wherein NSC_j means number of the references from Journal *j*, IF_j means the Impact Factor of Journal *j*, and *m* means there are *m* kinds of journals appeared in these references of this given patent document.

8. Standardization Impact (STI)
This indicator is created to assess essentiality of the given patent document in its subject. For some major industrial standard organizations, there is strict patent evaluation mechanism with special panel or committee. Once regarded as an essential patent in an industrial standard by some organizations, the core status of the given patent document in its subject is undoubted. STI indicator is valued as the number of the industrial standards to which the patent is required.

9. Standardization Scope (STS)
The STS is the extending of the STI indicator, leveling the corresponding standard organizations such as international, national, ministerial or occupational. It weights the given documents by the levels of their corresponding standard organizations to discover their influence scope.

Market Attribute

Three criteria are used to assess this attribute: Patent Family, Input Strength and Technology Commercialization. The following 7 indicators are derived whereupon.

1. Patent Family Size
Patent "family size" is computed as the number of jurisdictions in which patent protection is sought for the same invention. A range of researches have argued out that information on family size may be particularly well suited as an indicator of the value of patent rights. Patents representing large international patent families are particularly valuable (Lanjouw, 1998) (Guellec, 2000) (Harhoff, 2003) (Lanjouw, 2004).

2. Share of the Triad (US, EP and JP) Patents in a Family
According to the pioneering work, the international market scope is usually related to the triad Europe, U.S., and Japan. The share of triad (US, EP and JP) patents in the family members is employed on the evaluation of the economic qualities of the companies (Ernst, 2003) (Fabry,

2006) (Dernis, 2007). In this study, we introduce this indicator as a metric to gauge the market situation of a given patent document.

3. Human Resource Input

In general, inventors listed in the patent documents are the persons who contribute substantively to the inventions. The inventor information has been regarded useful to the inventor assessment and even the R&D team-building (Moehrle, 2005). In this study, we employed the number of the inventors listed in a patent document to scale the human resource input of the technology recorded in this given document.

4. Collaboration Intensity

Co-operation intensity is valued as the number of joint-owner with co-applicants, accessing of a firm to external know-how (and identification of partners) (Ernst, 2003) (Fabry, 2006). In this study, it is measured as the number of joint patent applications in given patent document to determine the players' focusing degree on this patent technology.

5. Self-Commercializing or Licensing

The comparable evaluation of patent commercialization and licensing effects are particularly useful to date. Successful commercialization means the high value of the patent technology (Arundel, 2006) (Xiao, 2008). This indicator is created in this study, which is valued by the times of the self-commercializing or licensing.

6. Patent Impawning or Collateral Loan

The pledge of patent right is concerning about the circulating of the intangible assets. It is a marketable representation of the patent value. The patent impawn counts and impawn ratio are regarded as value indicators by pioneering study (Huang, 2004) (Xiao, 2008). Here the pledge counts and pledge amount are introduced to evaluate the technology in the given patent document.

7. Patent Assignment

In general opinion, the patent, which has been or is going to be commercialized, has more possibility of assignment. More patent assignments mean greater economical potential. It is obvious in the activities of M & A, business inviting and capital attracting (Huang, 2004) (Xiao, 2008). We introduce it as a value index here.

Legal Attribute

This attribute is reviewed by two criteria: Number of years of a patent is renewed, and Current Legal Status. They are discovered by 6 indicators.

1. Patent Validity Year

In most countries, patentees must pay an annual renewal fee in order to keep their patents in force. The patentees earn the implicit return to patent protection during the coming year. The renewal fee varies with the age. Patentees would maximize the discounted value of net returns according to the patent by choosing an optimal age at which to stop paying the renewal fee. Schankerman et al. use an economic model of the renewal decision to recover the distribution of the values of the patents (Schankerman, 1986). In our study, patent validity year is employed as an indicator.

2. Patent Term Extension

The statutory patent terms range from zero years to 20 years. To date term limits have been set in an ad hoc fashion, usually to cover patent office costs. Scherer notes that the patents kept in force until the statutory limit of patent protection are significantly more valuable than other patents (Scherer, 1996). Previous study finds the other value indicators of the patents renewed until the statutory term limit are higher than those which are failed to the statutory term length (Lanjouw, 1998). Hence if the patent is renewed to the full term is introduced here as an indicator.

3. Survived from Patent Opposition Claim(s)

Pioneering study points out that opposition to patents granted by the European Patent Office (feasible within 9 months after the grant) can be helpful in assessing the value of patent rights. It is also suggested that the opposition system of the European Patent Office appears to be employed far more frequently than the USPTO's reexamination procedure and may thus be far more effective in weeding out weak patents. These researches insist that opposed patents are likely valuable, and that a successful defense of the patent against opposition is an interesting indicator of patent value (van der Drift, 1989) (Merges, 1999) (Harhoff, 2003).

4. Survived from Patent Annulment Claim(s or Litigations)

It is found that more valuable patents and those with domestic owners are considerably more likely to be involved in litigation (Lanjouw, 1997). And when innovations are more valuable or they form the basis for a sequence of technologically-related innovations held by the patentee, the litigation rates are higher (Lanjouw, 2000). Since the cost of litigation or annulment claims is much higher than that of opposition, researchers anticipate that successfully withstood annulment should be a stronger indicator of the patent's value than successfully defeated opposition (Harhoff, 2003). Hence litigation and annulment data may yield very attractive indicator for an approximation of patent value rights.

5. Granted

Only when granted, the novelty, inventiveness and practical applicability are guaranteed by the examinations. Hence the documents of granted patents are more valuable than those of patent applications.

6. Stability of Legal Status

Incorporating the fuzzy set theory, this indicator is to judge the stability of the granted patents, by discussing the current legal status up to the analyzing date. Some fuzzy numbers are designed to represent the importance of different legal status, such as patent expiration, maintenance, abandonment or annulment. Hence a fuzzy judge set is constructed, by which each patent document is evaluated according to its current legal status.

Methodology

Analytic hierarchical Process

AHP is a powerful decision analysis technique for the multi-criteria decision-making. It is a useful approach for evaluating a large number of quantitative and qualitative factors in a systematic manner. AHP decomposes problems into a hierarchy of a goal, attributes, criteria and alternatives.

The Delphi is combined to AHP to weigh the attributes. A peer review is conducted among experts. With a 9-point ratio scale (Table 1), the pairwise comparisons are used to weigh the relative importance of criteria, so as to identify and prioritize the criteria and alternatives.

Table 1. Pairwise comparison scale

9-point ratio scale	principle
1	Tow elements contribute equally
3	One element is slightly favored over another
5	One element is strongly favored over another
7	One element is very strongly favored over another
9	One element is most favored over another
2, 4, 6, 8	Adjacent to the two scales

Applying AHP, the decision-maker weighs the indicators in the pairwise comparison matrix, $A = a_{ij})_{nxn}$. By square root method, the eigenvectors of the judgment matrix are calculated as Formula 1.

$$\overline{W_i} = (\prod_{j=1}^{n} a_{ij})^{1/n} \qquad (i = 1, 2, \cdots, n) \tag{1}$$

Following, normalizing $\overline{W_i}$ as Formula 2.

$$W_i = \frac{\overline{W_i}}{\sum_{i=1}^{n} \overline{W_i}} \tag{2}$$

Then, $W = [W_1, W_2, \cdots, W_n]^T$ are the relative weights of the indicators.

The check for consistency is necessary. If a_{ij} represents the importance of element i over element j and a_{jk} represents the importance of element j over element k, $a_{ij}*a_{jk}$ must be equal to a_{ik}, which is an estimate of the relative weight of element i to k, W_i / W_k. If matrix A is not a non-zero vector, there is a $\lambda_{\max}$ of $Ax = \lambda_{\max}$, which is the largest eigenvector of matrix A. If the pairwise comparison matrix is perfectly consistent, then $\lambda = n$ and $CR = 0$.

The consistency ration (CR) is measured by the ratio of the consistency index (CI) to the random index (RI) as Formula 4. The CI values are calculated as Formula 3, with the values of RI described in Table 2. Several rounds of peer-review may be conducted until the CR is between 0 and 0.1. Then, by pairwise comparisons and relation matrix algebra, the overall weights of the elements are calculated (Saaty, 1980).

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{3}$$

$$CR = \frac{CI}{RI} \tag{4}$$

Table 2. Random index

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Delphi Questionnaires

Delphi questionnaires of interviews are used to gather criteria weight judgments. In this study, to increase the accuracy of estimation, the panel comprises 9 experts including the Technology Commercialization and Liaison Officers from an American research university of

Ivy League, the patent attorney from an international patent firm in Korean who once acted as an examiner at Korean Intellectual Property Office (KIPO), the technology manager from the headquarters of a corporation of Fortune 500, and the inventors from the labs of American and Chinese research universities. These panelists have abundant experiences in patent pricing, technology transfer, inventing and patent asset management.

Group Decision-Making Model

Group decision-making (GDM) is an active area of research within multi-criteria decision-making (MCDM). In AHP, there are several possible ways to aggregate information from the individual panelists to make a final group decision. In any case, the relative importance of the decision-makers may either be assumed to be equal, or else incorporated in the aggregation process (Ernest, 1998).

In this study, attention is given to the situation that individual members of the expert panel are considered non-equivalent in their importance within the group. A *Trust Index* is defined for each member depending on their perceived individual levels of importance, which attenuates the limitations of subjective impact from an individual by re-adjusting more value to each member. The adjusted evidence from each member is then combined to synthesize the group's collective decision.

In assigning the *Trust Index* to each member and synthesizing the judgment matrix, a method proposed by Li is applied in this study.

If matrix A_k is the individual pairwise comparison from the kth expert, his *Trust Index* P_k is inversely proportional to the A_k's consistent index μ_k which can be measured based on the largest eigenvector $\lambda_{\max}^{(k)}$ of A_k, as Formula 5 and 6. Then, based on the theory of Maximum Likelihood Estimation, the maximum Likelihood and unbiased estimated parameter of each element in synthetic judgement matrix is constructed finally as Formula 7 (Li, 2002).

$$\mu_k = \frac{\lambda_{\max}^{(k)} - n}{n-1} \qquad (k = 1, 2, \cdots, m) \tag{5}$$

$$P_k = \frac{e^{-10(m-1)\mu_k}}{\sum_{k=1}^{m} e^{-10(m-1)\mu_k}} \tag{6}$$

$$\hat{a}_{ij}^{*} = \frac{\sum_{k=1}^{m} P_k a_{ij}^{(k)}}{\sum_{k=1}^{m} P_k} \tag{7}$$

Results

By the approach presented above, the evaluation system for core patent documents identifying is established successfully as following.

Evaluation Hierarchical Structure and Weighting Values

Our evaluation hierarchy is structured as Table 3, with 3 attributes in level 1, 9 criteria in level 2 and 22 factors in level 3.

The combination of AHP and Delphi is applied to weigh the attributes, with the Maximum Likelihood and Unbiased Estimation to synthesize the experts' individual decision. MatLab software is employed for the matrix calculation. Finally, the overall weights of the attributes of our evaluation system are figured out (Shown in Table 3).

Table 3 Core patent documents evaluation hierarchy structure and weights

Goal	Attribute (Level 1)	Weight	Criteria (Level 2)	Weight	Indicators (Level 3)	Weight
Core patent documents evaluation	Technology Attribute (A)	0.23305	Technology Scope (TS) (A_1)	0.02535	Number of IPC (A_{11})	0.00546
					Number of Claims (CLN) (A_{12})	0.01989
			Technology Impact (TI) (A_2)	0.07274	Technology Dependence (A_{21})	0.04766
					Technology Cycle Time (TCT) (A_{22})	0.02508
			Science Strength (A_3)	0.00906	Science Linkage (SL) (A_{31})	0.00281
					Science Cycle Time (SCT) (A_{32})	0.00304
					Science Impact (SI) (A_{33})	0.00321
			Standardization Activity (A_4)	0.12590	Standardization Impact (A_{41})	0.05136
					Standardization Scope (A_{42})	0.07454
	Market Attribute (B)	0.46502	Patent Family (B_1)	0.13108	Patent Family Size (B_{11})	0.02831
					Share of the Triad (US, EP and JP) Patents in a Family (B_{12})	0.10277
			Input Strength (B_2)	0.05252	Human Resource Input (B_{21})	0.02408
					Collaboration Intensity (B_{22})	0.02844
			Technology Commercialization (B_3)	0.28142	Self-Commercializing or Licensing (B_{31})	0.17591
					Patent Impawning or Collateral Loan (B_{32})	0.03548
					Patent Assignment (B_{33})	0.07004
	Legal Attribute (C)	0.30193	Number of years of a patent is renewed (C_1)	0.14010	Patent Validity Years (C_{11})	0.01899
					Extended (C_{12})	0.01191
					Survived from Patent Opposition Claim(s) (C_{13})	0.05542
					Survived from Patent Annulment Claim(s) (C_{14})	0.05378
			Current Legal Status (C_2)	0.16183	Granted (C_{21})	0.06524
					Stability of Legal Status (C_{22})	0.09659

Evaluation model

The evaluation model is constructed by Simple Additive Weights (SAW) method. For m indicators and n patent documents on a certain subject, the final appraisal score C_i for each ith patent document is computed by multiplying the jth indicator importance weight w_j by the value of the ith patent document on the jth indicator. The preference is then ordered according to the score. The patent documents that have the highest scores are chosen as the core patent documents. The core patent documents (C^*) is selected such that

$$C^* = \left\{ C_i \middle| \max_i \sum_{j=1}^{m} w_j x_{ij} \right\}, \qquad i = 1,2,\cdots,n \tag{8}$$

Wherein x_{ij} is the value of the jth indicator on the ith document.

Conclusions

In this study, we succeed in establishing an indicator system for core patent documents evaluation. Different from other patent value systems, our system focuses on the key documents identifying, with most of the indicators available from public patent data banks. We combine AHP and Delphi Questionnaires as the primary approach, with a group decision-making model basing on the Maximum Likelihood and Unbiased Estimation theory. Our work could facilitate practitioners in patent information analysis, patent valuation and patent pricing.

Also, further efforts could be taken to advance this study. For example, more dimensions and indicators could be included, and there may be some other statistic methods suitable for the evaluation model. All these will be in our forthcoming research. More recently, one further research idea is about the application of this evaluation system. This could be addressed through an empirical research, which is already on our schedule.

Acknowledgements

We are sincerely grateful to dedicate our acknowledgements to the expert peer-reviewers. Also we deeply appreciate the financial supports to this research from the Knowledge Innovation Program of the Chinese Academy of Sciences and West Light Foundation of the Chinese Academy of Sciences.

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