EVALUATING PATENT PORTFOLIOS BY MEANS OF MULTICRITERIA ANALYSIS[1]

EVALUACIÓN DE CARTERAS DE PATENTES MEDIANTE ANÁLISIS MULTICRITERIO

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ABSTRACT

Valuation of intangible assets is a complex topic where traditional methodologies are not always successful. Nevertheless, intangible assets, like patents, have become of great importance to companies, as their value is considered to be relevant economic and strategic information, so it is necessary to evaluate firms' patent portfolios. The present research introduces an extended goal programming model to calculate the relative importance of the patents of companies in a patent pool. This information may be useful for patent valuation as well as for management purposes. The proposed multicriteria methodology has been applied to the 19 companies in the MPEG2 patent pool, with a total of 770 valid patents, using 7 criteria to obtain a composite measure of the relative position of the firms in the patent pool.

KEY WORDS: Patent assessment, Multicriteria analysis, Goal Programming, Firm ranking, Strategic management.

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RESUMEN

La valoración de activos intangibles constituye un área compleja donde los métodos tradicionales no siempre obtienen buenos resultados. Sin embargo, los activos intangibles, entre ellos las patentes, han ganado importancia en las empresas, de forma que el cálculo de su valor se ha convertido en una cuestión estratégica en muchos casos. Este hecho requiere que las empresas valoren la cartera de patentes en su conjunto. La presente investigación presenta un modelo extendido de programación por metas y su aplicación para el cálculo de la importancia relativa de las patentes. Este modelo puede resultar importante tanto para la valoración de las patentes como para la gestión empresarial. La metodología multicriterio propuesta ha sido aplicado a 19 empresas en el sector de las patentes del formato MPEG2, con un total de 770 patentes válidas, y utilizando 7 criterios con el objetivo de obtener una medida compuesta de la posición relativa de las empresas en el conjunto de patentes.

PALABRAS CLAVE: Valoración de patentes, Análisis multicriterio, Programación por Metas, Ranking de empresas, Gestión estratégica.

1 INTRODUCTION

As an essential part of companies' intangible assets, patents and patent statistics have long been scrutinized by researchers. In recent years, patent assessment has been used not only to evaluate company innovation level or competition status within a given industry but also in applied for patent portfolio analysis as part of corporate strategy. Innovators spare no efforts on R&D investment, aiming for substantial royalty return from licensing. *Like the primary research on* intangible assets pricing, this paper introduces a patent portfolio evaluation method based on multicriteria analysis. By applying this technological performance analysis, a better estimation of the relative standing within one's sector can be revealed for stakeholders such as shareholders, executives, suppliers, clients, employees, creditors and also for technological analysts, consultants and even competitors who have no direct connection with the firm.

Building on earlier works by Pakes (1986), Harhoff *et al.* (2003) and Reitzig (2004) it turns out that evaluation approaches using patent indicators seem especially convenient for assessing patent portfolios with a large number of patent characteristics. Many studies use a single indicator (raw patent counts, patent citations, patent length and breadth, or patent claims), arguing that the specific indicator that is applied has fewer shortcomings than others. Some studies use more indicators to generate one conduct, in which individual indicators are weighted either directly (interviews or surveys with experts) or indirectly (factor analysis). Instead of assuming the correctness of a single indicator, in this paper, 7 validated indicators drawn from publicly available patent databases are computed for individual patents that can then be fed into evaluation algorithms yielding the patent portfolio value of companies. This multi-criteria analysis allows us to establish a more complex, informative, objective model for composite measure of patent portfolio analysis and corporate innovation competition position within a specific industry.

The aim of this work is to elaborate easy-to-understand information that shows the relative importance of the patents of a company in a patent pool. This information can be used by patent valuers and top management to define the strategic planning of the companies. Notice that the aim of this research is not to economically value a patent pool, but to rank firms according to the importance of their patents. In contrast to other methodologies like the Analytic Hierarchy Process (AHP), our proposal only considers quantitative information about patents to reduce the subjectivity of the process of quantifying qualitative information. This is the main difference compared to previous studies.

Another important question is the simultaneous consideration of several indicators about patents in order to construct the ranking. Other approaches usually focus on a single measure, so the ranking can be very different depending on the selected indicator, and cannot be considered a reliable ranking because only a particular dimension of the patents firm is taken into account. In such cases, one alternative can rank the first position when a particular variable is considered, but a much lower position if another variable is considered instead.

Thus, the proposed methodology enables to evaluate patents from a multicriteria perspective. The evaluation of their patents can be very informative both for the firm and stakeholders, which can make their investment decisions taking into account this information.

The remainder of the paper is structured as follows. The next Section resumes previous research into patent evaluation. Section 3 introduces the proposed methodology. Then, in Section 4, the indicators used in the multicriteria model to evaluate patent pools are defined. Section 5 applies the new methodology to the evaluation of the MPEG2 patent pool. Finally, the conclusions and possible topics for further research are discussed.

2 BACKGROUND

Harhoff and Reitzig (2002) combine estimates of the patent right's value from a survey of patent holders with a set of indicators in order to adopt a regression model and suggest that patent's citations, family size and opposition are positively related to its value. Later, Harhoff *et al.* (2003) conclude that references to the non-patent literature are informative about the value of pharmaceutical and chemical patents, but not in other technical fields analyzed by these authors.

Hagedoorn and Cloodt (2003) studied the innovative performance of nearly 1,200 companies in four high-tech industries using a two-stage factor analysis and compositely construct a latent variable 'innovative performance' based on four indicators. The latent variable gives innovative performance of companies a broad, overall interpretation by taking into considerations different indicators. Lanjouw and Schankerman (2004) also constructed a factor model and developed a minimum-variance index of patent 'quality' based on three patent indicators- number of claims, forward citations, backward citations. These multiple indicators reduced the variance in patent quality considerably, and confirmed that quantitative information could gain from exploiting detailed patent characteristics.

Van Pottelsberghe and van Zeebroeck (2008) propose the scope-year index as an indicator of patent value, by combining both the renewal of patents and their geographical scope. However no theoretical justification on how to combine these two dimensions is provided. Reitzig (2004) analyzes the appropriateness of the 13 best-known indicators for business purposes by 23 empirical studies related to patent value and exploited more indicators of patent value by looking into patent attorney's filing rationales to enhance the quality of existing valuation methods.

Patent valuation is a topic that has also received great attention from researchers. Gambardella *et al.* (2006) try to estimate the determinants of the private economic value of patents from a questionnaire survey of European EPO patents. They find that the characteristics of the individual investor are a more important determinant of the private value of patents than the characteristics of the organization in which he or she works. Bessen (2008) examines the value drivers of patents, controlling both for patent and owner characteristics. He finds that U.S. patent values are higher on average than estimates for European patents, but the ratio of U.S. patent value to R&D for firms is only about 3%. He also concludes that patent citations explain little variance in value, suggesting limits to their use as a measure of patent quality.

These findings may support the inclusion of intangible variables in the valuation process of patents. As an example of this, Chiu and Chen (2007) use AHP to quantify some qualitative variables. They propose an objective scoring system for intellectual property patents from the licensor side. When no quantitative information is available, an expert must determine the relative importance of each patent valuation dimension.

More traditional methodologies have been also used in the valuation of patents, like discounted cash flow and option based methods (Pitkethly, 1997). However, none of these approaches are applied in our research because the aim of the paper is not to value a particular patent.

3 METHODOLOGY

It has become acknowledged that single-criterion valuation of patents has limitations of unthoroughness and distortion. Evidently, involving a number of incommensurable factors in generating the composite index for patent evaluation is the alternative, and this falls into the category of Multiple Criteria Analysis. Multiple Criteria Decision Making (MCDM) approach retains the advantages and enables exploiting of detailed information from individual indicators.

The essential issue in multi-criteria evaluation is to determine the weights of each factor and there are two fundamentally different ways to do so (Zeleny, 1982). One is direct explication, in which interviews, questionnaire surveys with experts are main determinants of factor weights. The other is indirect explication, in which the weights are determined objectively, for example via regression analysis or mathematical programming techniques based on the observed samples. In this paper, we compose an Extended Goal Programming approach to analyze the relative patent value in patent pools.

Goal programming (GP) is a branch of Multicriteria Decision Making Methodology (MCDM). It is essentially an extension or generalization of linear programming to handle multiple, normally conflicting objective measures. Each of these measures is given a goal or target value to be achieved and unwanted deviations from this set of target values are then minimized in an achievement function. GP was first introduced by Charnes, Cooper and Ferguson in 1955 in a model for executive compensation. Numerous subsequent studies have been following this approach, seminal works by Lee (1972), Ignizio (1976), and Romero (1991) followed.

Depending on the norm used, the solution arrived at can be interpreted either as one in which the consensus between all the measures is maximized (penalizing the more conflicting measures in favor of those that are more representative of the majority trend) or as one where preference is given to the most conflicting measures (thereby penalizing the measures that share the most information with the rest). In the first case, the absolute difference between the multi-criteria performance and the single-criterion performances is minimized (norm L_1); in the second case, it is the greatest difference between the multi-criteria performance and the single-criterion performances that is minimized (norm L_∞).

The model in norm L_1 is shown in [1].

Achievement function:

$$Min \sum_{i=1}^{n} \sum_{j=1}^{c} (n_{ij} + p_{ij})$$

s.t.

Goals:

$$\sum_{j=1}^{c} w_j v_{ij} + n_{ij} - p_{ij} = v_{ij} \quad i=1, \ldots, n, \; j=1, \ldots, c \qquad [1]$$

Hard constraint:

$$\sum_{j=1}^{c} w_j = 1$$

Accounting rows:

$$\sum_{j=1}^{c} w_j v_{ij} = V_i$$

$$\sum_{i=1}^{n} (n_{ij} + p_{ij}) = D_j$$

$$\sum_{j=1}^{c} D_j = Z$$

Where:

w_j=weight to be attributed to the j^{th} criterion.

$n_{ij}\,(p_{ij})$=negative (positive) deviation variable. It quantifies the difference by excess or deficiency between the value of the i^{th} firm in the j^{th} criterion and the multi-criteria performance that results from applying the weights w_j; that is to say, $n_{ij} - p_{ij} = v_{ij} - \sum_{j=1}^{c} w_j v_{ij}$, with $n_{ij}, p_{ij} \geq 0$. The achievement function assures that only one of the two deviation variables can be greater than zero: $n_{ij} \times p_{ij} = 0$.

D_j=degree of discrepancy between the j^{th} performance and the multi-criteria performance.

Z =accounting of the overall discrepancy.

Model [1] has $n \times c$ constraints labeled as 'goals'. This means that for each criterion j ($j=1,\ldots,c$) the model computes n constraints, one per firm i ($i=1,\ldots,n$), and must determine the value of the weight associated with criterion j, w_j. This can be achieved by minimizing the absolute difference between the performance of each firm in criterion j, v_{ij}, and the computed multi-criteria performance V_i, with $V_i = \sum_{j=1}^{c} w_j v_{ij}$.

The value of the achievement function provides the degree to which the set of goals remains unsatisfied; that is, the difference in absolute terms between the multi-criteria performance and the set of single-criterion performances. Weights are normalized so that their sum is equal to 1 (hard constraint). The final restrictions (accounting rows) serve to compute the multi-criteria performance of the firms (V_i), the degree of discrepancy between each single-criterion performance measure and the multi-criteria performance (D_j) and the degree of overall deviation (Z). In the literature, the model that minimizes the sum of discrepancies in absolute value is called the weighted GP model (WGP).

The norm L_∞ is implemented by the GP model called MINMAX [2], in which D represents the maximum deviation between the multi-criteria performance and the single-criterion performances. The remainder of the variables keeps the same significance as in [1].

Achievement function:

$Min \;\; D$

s.t.

Goals:

$$\sum_{j=1}^{c} w_j v_{ij} + n_{ij} - p_{ij} = v_{ij} \quad i=1, \ldots, n, j=1, \ldots, c \qquad [2]$$

Hard constraints:

$$\sum_{i=1}^{n} (n_{ij} + p_{ij}) \leq D \quad \text{j=1, …, c}$$

$$\sum_{j=1}^{c} w_j = 1$$

Accounting rows of model [1]

The solutions from both models represent extreme cases in which two contrasting strategies are set against one another: giving the advantage to the general consensus (WGP) or giving it to the conflicting performance measures (MINMAX GP).

There is an option that is of interest if one is seeking to find a compromise between [1] and [2]; it is to have recourse to an extended GP model, in which the λ parameter makes it possible to arrive at a more balanced solutions -model [3]-. Furthermore, solutions are sometimes more efficient in the D-Z plane. With the extended model, decision makers obtain alternative compromise solutions according to the value they assign to the λ parameter, and this broadens the range of possibilities when they have to decide what multicriteria performance is best suited to and the most representative of the single-criterion performances. Observe in [3] how if λ=1, the same solution is obtained as in model [1]; whereas in the case of λ=0, the solution coincides with that of model [2].

Achievement function:

$$Min\ \lambda \sum_{i=1}^{n} \sum_{j=1}^{c} (n_{ij} + p_{ij}) + (1-\lambda) D$$

s.t.

Goals:

$$\sum_{j=1}^{c} w_j v_{ij} + n_{ij} - p_{ij} = v_{ij} \quad \text{i=1, …, n, j=1, …, c}$$

Hard constraints of model [2]

Accounting rows of model [1] [3]

It may be the case that the decision maker has a neutral position regarding the value of λ. This means, for the decision maker there is no value of λ which is better than the others. Under this circumstance it is possible to elaborate one single ranking out of the rankings obtained for the different values of λ, simply by calculating the mean of the values obtained by the multicriteria performance for the different values of λ.

4 INDICATORS USED IN THE MULTICRITERIA MODEL TO EVALUATE PATENT POOLS

As a major form of technological innovation, the value of patent right has been examined using various criteria. The scientific linkage between backward citations and patent value has been introduced by Narin *et al.* (1997) and then has been validated as indicators of patent value by Harhoff *et al.* (2003), Hagedoorn and Cloodt (2003), Lanjouw and Schankerman (2004). Citations received from subsequent arts, also known as forward citations, have also been proved as an appropriate indicator of patent value by Trajtenberg (1990), Albert *et al.* (1991), Harhoff *et al.* (2003), Lanjouw and Schankerman (2004), Reitzig (2004). Family size has been validated as a patent right indicator by Putnam (1996), Lanjouw and Schankerman (2001), Harhoff and Reitzig (2002) and Reitzig (2004). Building on earlier work by Pakes (1986), Harhoff *et al.* (2003), constructive work done by Reitzig (2004) tests 13 well known measures of the value of patent rights and provides the evaluation of patent rights from a corporate perspective. Other indicators such as claims, ownership and oppositions have also been examined by Reitzig (2004). Based on the prior work, we use the following publicly available patent characteristics as indicators in our Extend Goal Programming model: patent counts, patent age, backward citations, forward citations, patent scope and family size. These are the usual variables patent evaluation, although others can be considered as well (Wang, 2007).

4.1 Patent Counts

It is generally accepted by now that raw patent counts alone are not a good measure of the inventive output of companies because of their bias and shortcomings (Archibugi, 1992; Cohen and Levin, 1989; Dosi, 1988; Griliches, 1998). However, in large parts of the economics literature, patent counts are widely applied as one of the most appropriate indicators for comparing innovative performance of companies engaged in technological competition, especially in the context of many high-tech sectors (Acs and Audretsch, 1989; Aspden, 1983; Bresman *et al.*, 1999; Freeman and Soete, 1997; Griliches, 1998; Patel and Pavitt, 1991; Pavitt, 1988).

4.2 Patent Age

From a theoretical point of view, the patent value model essentially assumes that the accumulated profit flows from patents increase monotonically during their lifetimes with exponentially decreasing marginal returns considering maintenance costs and emerging new technology. Moreover, Matutes *et al.* (1996) take technology cycles into account and strongly suggest that patent returns per period are not constant, but rather increase to the global maximum of the technology cycle and then decrease again. Therefore, given the fact that patent value is discounted with the passage of time, we assume that older patents are less valuable.

4.3 Backward Citations

The concept of 'scientific linkage' between patent value and references to prior patents and non-patent literature was introduced by Carpenter *et al.* (1981) and the analytical pioneer work was carried out by Narin *et al.* (1997).

From a theoretical and applied standpoint, backward citations are valid correlates to patent value. Backward citations of patents are theorized to demonstrate the technical novelty of a patent since through various references cited

Narin *et al.* (1997) and Harhoff *et al.* (2003) indicated that the measure for references to the patent literature (backward citations) has a significant positive correlation with patent value in all technical fields. Furthermore, a large number of citations to others also suggest that the particular innovation is likely to be more derivative in nature (Lanjouw and Schankerman, 2001).

On the other hand, however, it is plausible that a relatively small scope and low monetary value should characterize a patent whose examination report contains a large number of backward citations. The point-out logic behind this argument is that a patent application seeking to protect an invention with broad scope might encourage the examiner to delineate the patent claims by inserting more references.

4.4 Citations Received from Subsequent Patents (Forward Citations)

It has long been argued that the value of patents can be assessed by looking at the frequency of citations that an innovation receives from subsequent works. The central hypothesis is that patent citations are indicative of technological significance or impacts, and are informative of the economic value of innovations as well. This suggestion received considerable support in Trajtenberg's (1990) study of a computed tomography scanner, in which forward citations had been introduced and validated as indicators of patent value. Evidence of the validity of forward citations as an indicator of the quality of innovations, in terms of the correlation between the number of citations received from subsequent patents and the value of patent rights have been found in numerous subsequent surveys, e.g. by Hagedoorn and Cloodt, 2003; Lanjouw and Schankerman, 2001; and Harhoff and Reitzig, 2002; Harhoff *et al.*, 2003. Lanjouw and Schankerman (2004) further pointed out that the lifecycle of forward citations very probably suggests the expectation of valuable technological areas.

4.5 Patent Scope

The scope of the patent is a strategic decision that has important tradeoffs for the innovator. Given that a patent is a set of exclusive rights granted for the patentee to maintain a limited monopoly, to make it harder for potential competitors to enter the patentee's market with non-infringing innovations, the broader the scope of the patent, the higher the protection (Green and Scotchmer, 1995; O'Donoghue *et al.*, 1998). However, this raises the likelihood of infringement and patent validity challenges by competitors and/or third parties which, if successful, will reduce the effective life of the patent (Merges and Nelson, 1990; Lerner, 1994; Lanjouw and Schankerman, 2001).

Theoretical patent literature in economics has modelled the tradeoff and suggests the optimal structure for a patent. Gilbert and Shapiro (1990) consider a setting in which broader patents are increasingly costly to society in terms of deadweight loss, therefore in this case, the optimal patent would be very narrow but perpetual. Klemperer (1990) considers a more realistic assumption in which consumers can switch either to a substitute within the same product class or to one in another product class. In this model, either narrow-but-long or broad-and-short patents could be the best. Lerner (1994) developed a proxy for patent scope measured by the number of four-digit International Patent Classification (IPC) and showed that the value of biotech companies increases with the 'scope' of the patents they hold. Although other results show that the measure of scope computed as the number of different four-digit IPC codes does not have explanatory power over patent value (Harhoff and Reitzig, 2002), it is a good approximation of patent scope. We follow Lerner's approach and generate the number of four-digit IPC codes in the publication document as a measure of a company's patent scope.

The breadth of patent protection sought for the innovation should also be reflected by its claims. The innovator specifies the technological territory over which protection is claimed and has an incentive to claim as much as possible (Lanjouw and Schankerman, 2001). Empirical studies show positive and significant correlations between the value of a patent and its number of claims (Tong and Frame 1992; Lanjouw and Schankerman 2001).

4.6 Family Size

In order to protect an innovation in multiple countries, a patentee must secure a patent in each country. The group of patents protecting the same innovation is called its 'family', also referred to as parallel patents. Putnam (1996) has argued that information on family size may be well suitable as an indicator of patent value. Because applying for protection in each country is costly, family size should be directly related to the expected cost of protecting an innovation and thus to the value of the innovation itself. Subsequent studies also show that the size of a patent family, measured as the number of jurisdictions in which a patent has been granted, is highly correlated with the value of patent rights. Furthermore, family size should reflect both the technological importance of the innovation and market opportunities (Lanjouw and Schankerman, 2004)

To account for the potential explanatory power of "family size", we obtained the number of nations in which protection for a particular invention was sought from the EPO database.

A brief summary of the variables used in the analysis and their corresponding units is presented in Table 1.

TABLE 1.- INFORMATION ABOUT PATENT CRITERIA

CRITERIA	DEFINITION	UNIT
Number of patents	Total valid patent counts	Number of patents
Patent age	Years between the patent registration and the date where they were collected in our research (2009-10-01)	Number of years
Scope	The number of digits used for technological protection	Number of digits
Backward citations	It is calculated as the ratio between the number of cited documents and the number of patents	Ratio
Forward citations	It is calculated as the ratio between the number of citing documents and the number of patents	Ratio
Number of claims	List of all the essential elements of the invention	Number of claims
Family size	Number of countries where the patent has protection	Number of countries

5 EMPIRICAL RESULTS AND DISCUSSION

In our study, we examine licensor companies in the MPEG2 patent pool. There are 25 licensors in the MPEG2 patent pool, and 19 of them have valid patents out of a total number of 770 within the patent pool when we collected the data based on the MPEG2 patent list on October 1, 2009. For all of the patents on the MPEG2 patent list, the value determinants are available from the European Patent Office. We must remark that a possible drawback of our research is the limited sample considered to run the model, so the results only can be considered taking this shortcoming into account.

In order to eliminate the skewness in patent data and avoid the danger of potential bias, we use the method proposed by Diakoulaki *et al.* (1992) to normalize the dataset by the rank.

$$v_{ij} = \frac{x_{ij} - \min\limits_{k=1..n}(x_{kj})}{\max\limits_{k=1..n}(x_{kj}) - \min\limits_{k=1..n}(x_{kj})} \quad i=1\ldots n,\ j=1\ldots c \qquad [4]$$

Normalized patent characteristics are presented in Table 2. A summary of basic statistics for the original variables can also be found in the last rows of Table 2.

TABLE 2.- NORMALIZED SINGLE-CRITERION MEASURES OF PATENT DATA

Company	No.of patents	Patent age	Scope (5 digit)	Backward citations	Forward citations	No. of claims	Family size (country)
ALCATEL LUCENT	0.0417	0.0563	0.1667	0.2030	0.0674	0.2000	0.2400
BRITISH TELECOMMUNICATIONS plc	0.0093	0.0085	0	0.6642	0.0674	0.3333	0.2400
CIF LICENSING, LLC	0.1898	0.1161	0.3333	0.5166	1	0.5167	0.5200
COLUMBIA UNIVERSITY	0.0370	0.2089	0	0.4982	0.0674	1	0.2000
FUJITSU	0.0231	0.1102	0	0.6089	0.1011	0.4167	0.1600
GE TECHNOLOGY DEVELOPMENT, INC.	0.3009	0.5440	1	0.3321	0.1273	0.1583	0.5200
HITACHI, LTD.	0.0185	0.1749	0	0	0.0022	0.0733	0
KDDI CORPORATION	0	0.0099	0	0	0.0337	0.0833	0.0400
LG ELECTRONICS	0.0093	0.4008	0.1667	0.0923	0.0112	0.0778	0.0400
MITSUBISHI	0.5417	0.3889	0.5000	1	0.0442	0.1911	0.5200
PANASONIC CORPORATION	0.2315	0.1940	0.3333	0.3059	0.0260	0.0500	0.2800
PHILIPS	0.2269	0.3103	0.8333	0.3875	0.0655	0.1556	0.3600
SAMSUNG ELECTRONICS CO., LTD.	0.0833	0.3266	0.3333	0.1937	0.0393	0.3854	0.2000
SANYO ELECTRIC CO., LTD.	0	0	0	0	0	0	0
SCIENTIFIC-ATLANTA LLC	0.0556	0.2386	0.3333	0.4797	0.7416	0.1389	0.3200
SONY	1	0.4172	0.8333	0.3730	0.2140	0.1949	1
THOMSON LICENSING	0.5278	1	1	0.3782	0.2725	0.1819	0.4400
TOSHIBA CORPORATION	0.0370	0.1803	0.1667	0.6421	0.3640	0.2133	0.0400
VICTOR COMPANY OF JAPAN, LIMITED (JVC)	0.1435	0.1454	0.3333	0.1265	0.1396	0.0167	0.2000
Minimum	1	5	1	0	0	2	1
Maximum	217	16	7	18	89	62	26
Mean	40.5	10.8	3.0	6.5	15.9	15.9	8.0
Median	13	10.9	3	6.7	6.0	12.9	7.0
Standard deviation	54.4	3.0	2.0	4.7	23.0	13.6	6.0

Note: Values for basic statistics have been calculated on original variables, not on the normalized ones.

The rankings are certainly not consistent based on different single criteria, except for company ‘SANYO’ with 0 for all criteria. Using the normalized data into the above mentioned extended Goal Programming model [3], we obtain the results in Table 3. In the extended GP model, the weight assigned to each indicator varies depending on the value of the λ parameter, as well as the degree of discrepancy between each single-criterion performance measure and multi-criteria performance (D_j) and the degree of overall deviation (Z).

TABLE 3.- RESULTS OF THE EXTENDED GP MODEL [3] FOR DIFFERENT VALUES OF λ

	No.of patents	Patent age	Scope (5 digit)	Backward citations	Forward citations	No. of claims	Family size (country)	D	Z
$\lambda=0$	0.1711	0.0081	0.3170	0.2611	0.0000	0.2427	0.0000	3.3333	19.8322
D_j	(2.6329)	(2.2500)	(3.3333)	(3.3333)	(3.3333)	(3.3333)	(1.6159)		
$\lambda=0.1$	0.1816	0.0713	0.1272	0.1586	0.0309	0.2117	0.2187	3.3576	19.4252
D_j	(2.3545)	(2.3232)	(3.3576)	(3.3576)	(3.2787)	(3.3576)	(1.3961)		
$\lambda=0.2$	0.1891	0.0830	0.0952	0.1382	0.0438	0.2060	0.2446	3.3642	19.3762
D_j	(2.3033)	(2.3465)	(3.3642)	(3.3642)	(3.2571)	(3.3642)	(1.3768)		
$\lambda=0.3$	0.1891	0.0830	0.0952	0.1382	0.0438	0.2060	0.2446	3.3642	19.3762
D_j	(2.3033)	(2.3465)	(3.3642)	(3.3642)	(3.2571)	(3.3642)	(1.3768)		
$\lambda=0.4$	0.1891	0.0830	0.0952	0.1382	0.0438	0.2060	0.2446	3.3642	19.3762
D_j	(2.3033)	(2.3465)	(3.3642)	(3.3642)	(3.2571)	(3.3642)	(1.3768)		
$\lambda=0.5$	0.1928	0.0888	0.0792	0.1280	0.0503	0.2032	0.2576	3.3675	19.3729
D_j	(2.2777)	(2.3731)	(3.3675)	(3.3675)	(3.2526)	(3.3675)	(1.3671)		
$\lambda=0.6$	0.2796	0.0384	0.0305	0.0834	0.0763	0.2205	0.2712	3.4360	19.3059
D_j	(2.0693)	(2.5866)	(3.4360)	(3.4360)	(3.2839)	(3.2174)	(1.2767)		
$\lambda=0.7$	0.2796	0.0384	0.0305	0.0834	0.0763	0.2205	0.2712	3.4360	19.3059
D_j	(2.0693)	(2.5866)	(3.4360)	(3.4360)	(3.2839)	(3.2174)	(1.2767)		
$\lambda=0.8$	0.2796	0.0384	0.0305	0.0834	0.0763	0.2205	0.2712	3.4360	19.3059
D_j	(2.0693)	(2.5866)	(3.4360)	(3.4360)	(3.2839)	(3.2174)	(1.2767)		
$\lambda=0.9$	0.2772	0.0233	0.1527	0.1206	0.0512	0.2059	0.1691	3.6137	19.2764
D_j	(2.1126)	(2.2749)	(3.1966)	(3.6137)	(3.4061)	(3.3850)	(1.2874)		
$\lambda=1$	0.2772	0.0233	0.1527	0.1206	0.0512	0.2059	0.1691	3.6137	19.2764
D_j	(2.1126)	(2.2749)	(3.1966)	(3.6137)	(3.4061)	(3.3850)	(1.2874)		

The output differs as the value of λ changes, so alternative solutions are provided. The WGP model produces the same solution as the extended one when λ=1. It assigns the greatest weights to 'No. of patents' (27.72%), 'Forward citations' (20.59%), 'Family size' (16.91%) and 'Scope' (15.27%) with a total weight of 75.64%. Consistent with this, the lowest value of *Z* is reached. This solution can be interpreted as these four characteristics are more representative of the majority trend, given that the consensus between all the measures is maximized.

The MINMAX GP model, with the same solution as the extended one with λ=0, offers a solution that is at the opposite extreme from the WGP. In this case, the multi-criteria model assigns more weights to 'Scope' (31.70%), 'No. of claims' (26.11%), and 'Forward citations' (24.27%) with a total weight of 82.08%. In the MINMAX GP model the greatest difference between the multi-criteria performance and the single-criterion performances is minimized. It can be deduced that the indicators 'Scope' and 'No. of claims' are given preference as the most conflicting measures whereas others λ like 'Family size' are given a weight of 0, being penalized for sharing most information with the other criteria. These two measures, 'Scope' and 'No. of claims' are referred to as 'second generation' and 'third generation' indicators by Reitzig (2004) because they are used to compute value proxies and are strongly correlated to the potential value of the patent portfolio. These indicators are appealing because although they do not directly suggest patent value, they do reveal a linkage with the technological breadth and depth of companies.

For any λ, indicators 'Patent age' and 'Backward citations' are assigned indistinctive weights. This is not surprising because the correlation between these characteristics and patent value are controversial in theory as stated above. Throughout all the situations in the extended GP model, both 'No. of patents' and 'Forward citations' are assigned with a weight around 20%, which is relatively high compared to others. As perceived from empirical results, for companies within the MPEG2 patent pool, the more obvious technology power lies in the direct quantitative indicators of patents, in this case the patent counts and the references received from subsequent papers.

Another interesting conclusion can be elicited when the Spearman correlation coefficient is calculated for the rankings according to the corresponding value of λ. Table 4 reports the Spearman correlation for rankings with λ=0, 0.25, 0.5, 0.75 and 1. All values are statistically significant for a confidence level of 99%, and the coefficients are in all cases above 93%. In fact, the same ranking is obtained for λ=0.25 and λ=0.5. This means that rankings are very similar regardless of the λ used in the goal programming model, and therefore the results are robust to this parameter.

TABLE 4.- SPEARMAN CORRELATION FOR RANKINGS WITH λ=0, 0.25, 0.5, 0.75 AND 1

	L=0	L=0,25	L=0,5	L=0,75	L=1
L=0	1	0,9754	0,9754	0,9316	0,9737
L=0,25		1	1,0000	0,9737	0,9912
L=0,5			1	0,9737	0,9912
L=0,75				1	0,9789
L=1					1

Using the information presented in Table 3 with the weights of the variables for the different values of λ, we obtained the multicriteria performance of the patents of the companies. Then, we ordered them from highest to lowest, obtaining 11 individual rankings, one for each value of λ. As our position towards the value of λ is eutral, so as not to give more importance to the criteria which reflect the majority trend nor to those with most discrepancy, it is possible to create a single ranking. To do so, we simply have to calculate the mean multicriteria performance obtained by each firm in the 11 rankings. Table 5 shows this final ranking.

TABLE 5.- FINAL RANKING WITH THE 19 COMPANIES IN THE MPEG2 PATENT POOL

COMPANY NAME	RANK	COMPANY NAME	RANK
SONY	1	TOSHIBA CORPORATION	11
CIF LICENSING, LLC	2	VICTOR COMPANY OF JAPAN, LIMITED (JVC)	12
THOMSON LICENSING	3	FUJITSU	13
MITSUBISHI	4	BRITISH TELECOMMUNICATIONS plc	14
GE TECHNOLOGY DEVELOPMENT, INC.	5	ALCATEL LUCENT	15
SCIENTIFIC-ATLANTA LLC	6	LG ELECTRONICS	16
PHILIPS	7	KDDI CORPORATION	17
COLUMBIA UNIVERSITY	8	HITACHI, LTD.	18
PANASONIC CORPORATION	9	SANYO ELECTRIC CO., LTD.	19
SAMSUNG ELECTRONICS CO., LTD.	10		

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6 CONCLUSION

In this paper, we propose an extended GP model to combine 7 measures of patent value and assess the relative position of the companies within a patent pool. According to what value is assigned to the λ parameter, the extended GP model produces different solutions between two extreme circumstances: decision makers can choose to what extent they want to emphasize the trend criteria or overweight the most deviant measures. In our analysis, alternatives between both options are presented for a number of quantitative patent measures and the potential patent value indicators. Based on the solutions generated through our extended GP model of patent evaluation, ranking of 19 licensors within MPEG2 patent pool has been proposed. The proposed methodology empowers decision makers to choose from various solutions the one which is best suited to their strategy for future innovation purposes. This paper does not claim to solve the applied problem of valuing patent portfolios from a corporate perspective. The truth is that the selection of the performance measures themselves inevitably brings some level of subjectivity. It is our consideration that the extended GP model serves to expand the latitude of methodologies for patent portfolio assessment. Based on the results derived from the empirical research, the multicriteria solution is optimal for patent evaluation in terms of taking all information into consideration. A main difference compared to other approaches like AHP is the consideration of only quantitative information, thereby reducing the subjectivity when including qualitative information. The multicriteria approach also enables the compilation of several patent-related indicators, and avoids ranking the patents pool based on only one particular indicator. Further research on the compilation of new indicators from patent portfolio valuation rationales would add new perspectives to the model. Moreover, conducting studies that combine company technological measures with financial indicators would also be of great interest in order to improve current patent valuation methodologies.

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