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Full Length Research Paper

Assessment on intellectual capital management for Taiwanese pharmaceutical industry: Using GRA and MPI

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In the new economy era, knowledge has already become the most vital enabler connection with a high technology enterprise. Intellectual capital is the core of knowledge management. Managing intellectual capital effectively can greatly enhance the competitive advantages of enterprises. The former studies about intellectual capital concentrated on its content and the stock measurement. This study focused on how to utilize intellectual capital more efficiently, in order to strengthen the competitiveness of enterprises. This research established a novel assessment model to measure the performance of intellectual capital management in two aspects, by using grey relational analysis to measure operational performance and Malmquist productivity index to judge productivity evolution. The research target is the Taiwanese pharmaceutical industry. The research collected data from the Listed Company Database of Taiwan Stock Exchange and the Department of Health of government during the period 2005 to 2008. A total of 12 major companies of Taiwan's pharmaceutical industry were chosen as empirical samples. The results demonstrated that, this novel assessment method really identify the relative advantages and benchmarking for pharmaceutical companies. F8 is the best company both in operational performance and productivity improvement. These results are very valuable for both academic study and business enhancement.

Key words: Grey relational analysis, Malmquist productivity index, intellectual capital.

INTRODUCTION

The competition model of business has changed from time to time. Knowledge has been recognized as one of the most important success factors to a company in many key aspects, such as innovation, quality and so on (Gholipour et al., 2010; Ooi, 2009). Today, the intangible assets of a company are more decisive than the physical assets. These assets are often referred to as the intellectual capital. As business shifts from an asset-centric environment to a knowledge-centric environment, the measures of intellectual capital have received more attention. The influence of intellectual capital on innovation is essential, Wu et al. (2008). Innovation management will eventually improve firm's competitiveness, Hidalgo and Albors (2008). The former studies about the intellectual capital were more focusing on its content and the stock measurement (Edvinsson and Malone, 1997; Sullivan, 2000; Bontis, 2001; Hermans and Kauranen, 2005). The study of intellectual capital management is not sufficient so far from the empirical point of view. On the other hand, how to use intellectual capital more effectively in order to promote organization performance certainly, is the most important subject for technology-driven enterprises.

Therefore, the pharmaceutical industry was chosen as the object for this study. It is worth noting that the pharmaceutical industry has to invest its resources constantly, in order to acquire intellectual property rights. Pharmaceutical companies who invest more in Research and Development (R&D) have more opportunities toward success. As a whole, intangible assets are getting more and more important. However, one of the key problems

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for many biotechnology pharmaceutical industries is their incapability of showing fair and measurable corporate and R&D value on financial reports. No measurement means no effective management.

This study mainly focuses on using Grey Relational Analysis (GRA) and Data Envelopment Analysis (DEA) to probe into intellectual capital management performance of Taiwan pharmaceutical industry. Every pharmaceutical company certainly has a unique operating model. However, for intellectual capital management ability, if some standards can be identified out of those outperformed companies through certain kinds of measurement methods, the results surely can offer improvement to other companies. This study emphasizes again that, intellectual capital is a very essential strategic asset and eventually help business to strengthen self-competitive advantage and promote corporate performance. The concept of intellectual capital was proposed by Galbraith in 1969. Galbraith theorized that, intellectual capital referred to intellectual action rather than pure intellect. He also argued that, intellectual capital exists as the most essential part of knowledge, which creates the differential advantages for companies.

In order to utilize valuable intellectual capital, organizations should set up valuable enterprise networks to connect internal cross-departmental groups and link them externally with customers and vendors for accelerating the creation of the value for the company. So far, there is no accord on a unique definition of Intellectual Capital, but Edvinsson and Malone (1997) gave a comprehensive view of Intellectual Capital as knowledge that can be converted into value. Stewart (1997) suggests three measures of intellectual capital at the organization level, 1) market-to-book ratio, 2) Tobin's q, and 3) calculated intangible value (CIV). This study adopts CIV method to measure the monetary value of intellectual capital stock. The CIV method can be used for comparisons among companies within the same industry and it is good for illustrating the financial value of intangible assets.

Stewart (1994) pointed out that, intellectual capital can bring organizations' competitive advantages with all knowledge and ability together. Also, the scholars and consultants who study this field of intellectual capital generally think that, it's the source of organization's competitive advantages (Edvinsson and Malone, 1997; Nahapiet and Ghoshal, 1998; Leapak and Snell, 1999). They also agreed that intellectual capital affects corporate organization performance. With more intellectual capital stocks, the organization performs better (Bontis, 1998; Riahi-Belkaoui, 2003; Mavridis, 2004). Narasimh et al. (2003) used DEA to determine relative efficiencies of 29 US pharmaceutical firms, and investigated the effects of technological knowledge on performance measures of the sample firms, and investigated the knowledge dimension that the inefficient firms ought to focus upon to improve their performance.

Eduardo and Fernando (2004) use DEA to analyze the evolution of the productivity patterns in a sample of 80 pharmaceutical laboratories that operated in Spain from 1994 to 2000; besides, they also estimate MPI and decompose them into four sources of productivity change.

Shao and Lin (2002) used DEA to investigate the effects of information technology on technical efficiency in a firm's production process through a two-stage analytical study with a firm-level data set. Liang et al. (2008) investigated production efficiency in the biotech industry by DEA before and after integration. In the study, the possible integrative targets of a particular Taiwanese biotech company were analyzed. Wu et al. (2006) adopted DEA and the Malmquist productivity index (MPI) to evaluate the impact of intellectual capital on competitive advantage. Chen et al. (2006) developed a DEA nonlinear programming model to evaluate the impact of information technology on multiple stages along with information on how to distribute the information technology-related resources, so that the efficiency is maximized.

The objective of this study is to establish a new assessment model to measure the intellectual capital of Taiwanese pharmaceutical companies. Through the adoption of GRA, we estimate the operational performance rankings of Taiwanese pharmaceutical companies. Through the adoption of MPI, we estimate the productivity change of these companies and decompose them into two sources of productivity change. Through the adoption of Kruskal-Wallis test, according to the factor "scale", we divide the decision making units (DMUs) into three groups. We will clarify whether these three productivity growth changes are different or not.

PROPOSED METHODOLOGY

This study uses GRA and DEA as the foundation and brought up a set of systematic assessment models. The research flow of this study is shown in Figure 1. Explanation of Figure 1 follows.

Stage one: Collect the data of pharmaceutical companies

1. Refer to domestic and foreign related literatures on DEA, and then determine the subject and which approach this paper will use.
2. Search pharmaceutical related enterprises to find all potential candidates to be the DMUs list.
3. Collect historical data on candidate companies.

In short, this study uses the listed pharmaceutical companies in Taiwan who are related to pharmacy products as DMUs. According to the rule of thumb (Golany and Roll, 1989), the regulation is the number of the assessed companies or at least it has to double the total number of input and output variables.

Stage two: Choose input/output variables

We did not only take into account the information on financial statements but also the intangible value of pharmaceutical industry, while we determined to select the initial input/output indicators. This

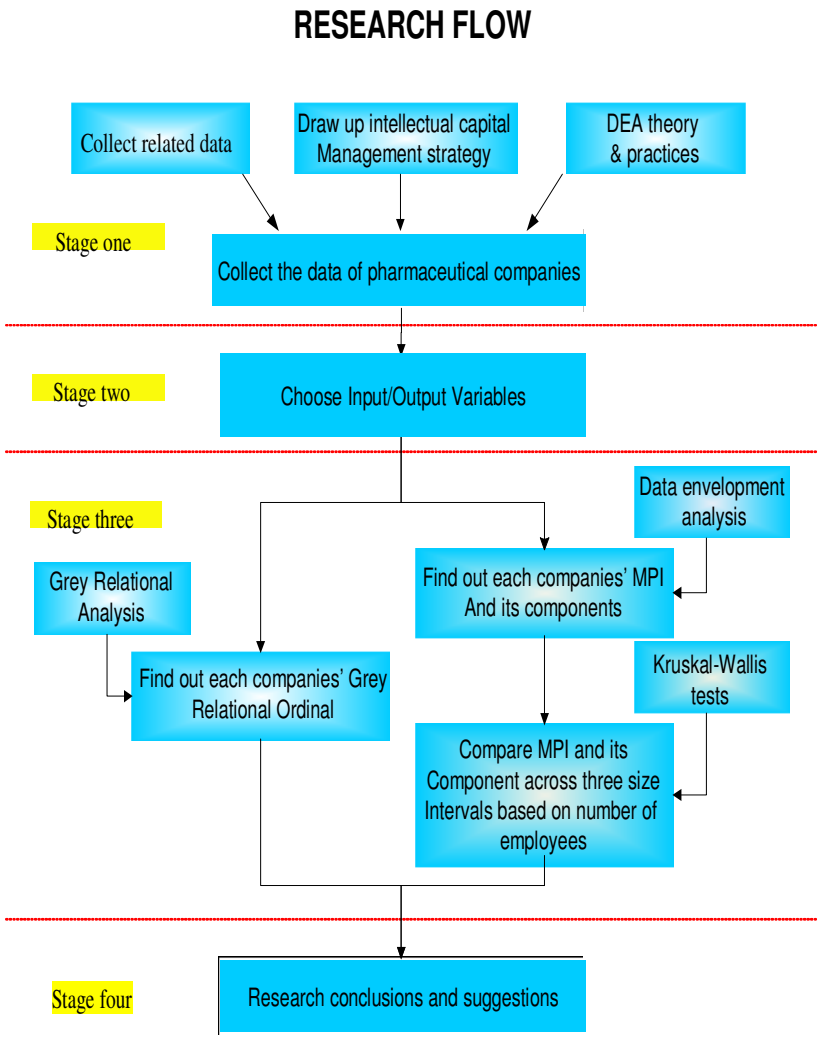

Figure 1. Research flow.

research further utilizes the intellectual capital perspective to select input / output variables. We firstly select the proper input and output variables while using grey relational analysis and data envelopment analysis methods. The pharmaceutical industry is a technology-intensive industry in terms of R&D and innovation aspects. According to the arguments of the researchers (Wu et al., 2006; Liang et al., 2008), the following indicators are selected as input measures; number of employees, R&D expenditures and intellectual capital.

However, this study is concerned with the metrics that can accurately reflect the relationship between intellectual capital and management performance in utilizing intellectual capital, human capital, R&D expenditures and drug licenses. This study adopts the following indicators as input variables. Number of employees is used to measure the human capital that a firm possesses. R&D expenditures are used to capture investment in firm core competences. Drug licenses indicate the number of drug licenses possessed by a company. Beginning intellectual capital stocks represents the monetary value of firm intellectual capital stocks, and was calculated by using the calculated intangible value (CIV) method. Similarly, based on literature mentioned before, the selected output indicators are: sales and intellectual capital stocks (Wu et al., 2006). The output variables adopted in this study are as follows. Ending intellectual capital stocks indicates the amount of intellectual capital remaining at the end of the year, which is used to measure the intangible value of business. The data of drug licenses was collected from the Department of Health, Executive Yuan, Taiwan, other data were collected from the market observation posting system of Taiwan Stock Exchange Cooperation during the period 2005 to 2008.

Stage three: Data analysis

Four items of input and two items of output variable were used as study factors. We apply the localization grey relational analysis to evaluate the working performance of Taiwanese pharmaceutical vendors' intellectual capital every year and the whole period in the past few years and understand the ordering variation situation.

Grey relational generating means add new information to the system's needs, based on the processed data used to find the rule of data. Hsia's method (Hsia and Wu, 1998) is adopted for definition and calculation. Furthermore, this study introduces Deng's grey relational grade (Deng, 1989). The complete concepts are described as follows.

1. Grey relational coefficient

$$\gamma(x_0(k), x_i(k)) = \frac{\min. + \zeta \Delta \max.}{\Delta_{0i}(k) + \zeta \Delta \max.} \quad (1)$$

Where

(a) $i = 1,2,3,...,m.\ k = 1,2,3,...,n.\ j \in i$

(b) x_0 : Reference sequence, x_i : Inspected sequence.

(c) $\Delta_{oi} = |x_0(k) - x_i(k)|$: The difference between x_0 and x_i (Norm).

(d) $\Delta_{\min} = \underset{j \in i}{\overset{\min.}{\forall}} \underset{k}{\overset{\min.}{\forall}} |x_0(k) - x_i(k)|$, $\Delta_{\max} = \underset{j \in i}{\overset{\max.}{\forall}} \underset{k}{\overset{\max.}{\forall}} |x_0(k) - x_i(k)|$

(e) ζ : Distinguishing coefficient, and $\zeta \in [0,1]$ this study uses 0.5.

2. Grey relational grade: the mean of grey relational coefficient

$$\Gamma_{oi} = \frac{1}{n} \sum_{k=1}^{n} \gamma(x_0(k), x_i(k)) \quad (2)$$

Because of no special request, we set that all β_k are equal, therefore, we extend the Equation (2) into

$$\gamma(x_i, x_j) = \sum_{k=1}^{n} \beta_k \gamma(x_i(k), x_j(k)) \quad (3)$$

Where β_k is the weighing for each factor, and $\sum_{k=1}^{n} \beta_k = 1$

3. Grey relational rank ordinal

After calculating the grey relational grade; according to the value, we can rank the sequence, and this procedure is called grey relational rank. For reference sequences x_0, and inspected sequences are x_i, where

$$x_0 = (x_0(k)), x_i = (x_i(k)),\ k = 1,2,3,...,n,\ i = 1,2,3,...,m \quad (4)$$

If

$$\gamma(x_0, x_i) \geq \gamma(x_0, xj) \quad (5)$$

Then we found that, under the reference sequence x_0, the grey relational rank of what is greater than grey relational rank of x_i is greater than grey relational rank of x_j.

This study uses DEA's Malmquist model by using pharmaceutical information of vendors to analyze efficiency change for all pharmaceutical companies and to measure technical efficiency scores during two particular periods. Secondly, the study analyzes technical change and measures the condition of efficiency frontier-shift between two particular periods. Finally, the study analyzes Malmquist productivity index and finds out the main reason of Malmquist productivity decline. Moreover, this study also carries out a comparison between the period efficiency and productivity change, in order to understand the situation of every annual growth and decline of efficiency and productivity. Following Caves et al. (1982), the output-based Malmquist productivity index is defined as follows:

$$\text{MPI} = \left[\frac{d_o^s(x_t, y_t)}{d_o^s(x_s, y_s)} \times \frac{d_o^t(x_t, y_t)}{d_o^t(x_s, y_s)} \right]^{1/2} \quad (6)$$

where d_o^s is a distance function, measuring the efficiency of conversion of inputs x_s to outputs y_s in the period *s*. (Note that DEA efficiency is considered as a distance measure in the literature, as it reflects the efficiency of converting inputs to outputs [Färe et al., 1994]). One important thing is that, if there is a technical change in period *t*, then,

$$d_o^t(x_s, y_s) = \text{Efficiency of conversion of input in period } s \text{ to output in period } s \neq d_o^s(x_s, y_s)$$

Malmquist productivity index is a geometric average of the efficiency and technical changes in the two periods being considered. Following Färe et al. (1994), the Malmquist productivity index in Equation (6) can thus be written as:

$$\text{MPI} = \frac{d_o^t(x_t, y_t)}{d_o^s(x_s, y_s)} \left[\frac{d_o^s(x_s, y_s)}{d_o^t(x_s, y_s)} \times \frac{d_o^s(x_t, y_t)}{d_o^t(x_t, y_t)} \right]^{1/2} = \text{Efficiencychange} \times \text{Technicalchange} \quad (7)$$

The study attempted to use Kruskal-Wallis test (Theodorsson-Norheim, 1986) of non-parametric statistics method and discuss the diversity situation of pharmaceutical factories' productivity growth change in different scale grade, in order to understand further if Taiwanese pharmaceutical industry management of intellectual capital shows difference due to different factory sizes.

Stage four: Research conclusions and suggestions

This study mainly focuses on using GRA and DEA to probe into intellectual capital management performance for Taiwan pharmaceutical companies. Through complete literature review, data collection, GRA, DEA and Kruskal-Wallis test (Theodorsson-Norheim, 1986) we can clearly understand the latest situation of Taiwanese pharmaceutical industry's management performance of intellectual capital application. Also, this study encourages further transparency and competitiveness promotion of corporate governance and offers the managers the information of traditional accounting financial report that cannot be assessed usually. We emphasize again that intellectual capital is an essential strategy tool

Table 1. Raw data of 12 Taiwan pharmaceutical companies (2008) NTD: New Taiwan Dollar.

Year	No.	Input				Output	
		No. of employees	R&D expenditures (NTD 1,000)	Pharmaceuticals permission	Intellectual capital stocks (beginning)	Net sales (NTD 1,000)	Intellectual capital stocks (end)
2008	F1	553	157933	557	-396533	2797049	-1639347
	F2	115	22413	37	-183507	280550	-199423
	F3	1127	239569	689	2228435	3128157	1860324
	F4	93	31082	40	237612	255966	224770
	F5	635	114613	598	634100	1742463	892544
	F6	641	115002	365	-475673	1456692	-792485
	F7	343	219849	67	404695	1786456	494766
	F8	89	14519	65	-53288	293992	144756
	F9	207	8842	177	-143106	565594	-296919
	F10	275	55610	176	-476573	736749	-639317
	F11	260	84622	93	37043	566948	-37552
	F12	147	24949	47	-400195	318616	-409221

that will assist business to strengthen self-competitive advantage and promote corporate performance.

RELTISTIC EXPERIMENTS AND RESEARCH RESULTS

Taiwan's biotechnology and pharmaceutical industry includes new biotechnology, pharmaceuticals and medical devices. This study is mainly based on the public financial reports filed by Taiwan stock exchange cooperation. This study uses companies who are related to pharmacy products as DMUs, which include producing and selling human and animal drugs. This research neglected the companies which have incomplete data. A total of 12 companies were chosen to be our DMU as empirical sample. The aggregated revenues of these 12 companies accounted for 53.3% of Taiwanese Biotechnology Taiwanese Biotechnology and Pharmaceutical industry revenues in 2008. We summarized the twelve companies' inputs and outputs in 2008 and show the data in Table 1. There are six input and output variations as mentioned before. This study used Grey Relation v.1.1 software built by Grey System Research Center, GSRC (Wen 2004) and applied localization grey relational analysis to evaluate the ranking of the 12 companies' intellectual capital performance in every year and the whole period from 2005 to 2008. The steps are as follows; when proceeding the part of localization grey relational analysis, the first step must set up referential sequence and comparative sequence. The study factors belong to the small identity, then select the minimum and the large identity, then select the maximum to set up referential sequence. So those 12 companies are comparative sequence.

When proceeding, the original data into the grey relational generation, it mainly deals with data processing of the original data that are yet to be true according to actual situation and promotion of the data's visualiziability. This study adopts Hsia's method (Hsia and Wu, 1998) and proceeds the original data of the employees' number, R&D expenditures and pharmaceuticals permission (the smaller the better), original data of intellectual capital stock (beginning), net sales and intellectual capital stock (end) (the larger the better). Then, calculate the grey relational coefficient and grey relational grade. Followed by the value of the grey relational grade, calculate the grey relational rank ordinal. As shown in Table 2, the top 3 ranking orders of 12 companies in 4 years are mainly F8, F4 and F2 as shown in Table 3. The top 3 average grey relation grade ranking order of 12 pharmaceutical companies from 2005 to 2008 is F8, F4 and F2 respectively. Higher grey relational grade means closer to referential sequence and

Table 2. The results of grey relational analysis for 12 Taiwan pharmaceutical companies.

Year	2005		2006		2007		2008	
No.	Grey relational grade	Rank	Grey relational grade	Rank	Grey relational grade	Rank	Grey relational grade	Rank
F1	0.4736	12	0.4635	12	0.4797	10	0.4726	11
F2	0.7120	3	0.6679	3	0.6420	4	0.6668	3
F3	0.6681	5	0.6667	4	0.6667	2	0.6667	4
F4	0.7417	2	0.6835	2	0.6613	3	0.6794	2
F5	0.5041	11	0.4794	10	0.4747	11	0.5799	7
F6	0.5070	10	0.4717	11	0.4495	12	0.4280	12
F7	0.6911	4	0.6035	7	0.5681	7	0.5742	8
F8	0.7605	1	0.6954	1	0.6716	1	0.6812	1
F9	0.6597	6	0.6094	6	0.5938	6	0.6141	6
F10	0.6245	9	0.5764	9	0.5450	9	0.5448	10
F11	0.6316	8	0.5768	8	0.5587	8	0.5716	9
F12	0.6593	7	0.6279	5	0.6319	5	0.6434	5

Table 3. Average grey relation grade of twelve Taiwan pharmaceutical companies (2005 to 2008).

Year	2005 to 2008	
No.	Average grey relation grade	Rank
F1	0.4724	11
F2	0.6722	3
F3	0.6671	4
F4	0.6915	2
F5	0.5095	10
F6	0.4641	12
F7	0.6092	7
F8	0.7022	1
F9	0.6193	6
F10	0.5727	9
F11	0.5847	8
F12	0.6406	5

Table 4. Annual average of productivity change and its components from 2005 to 2008.

No.	2005=>2008 Annual average efficiency change	2005=>2008 Annual average technique change	2005=>2008 Annual average productivity change (MPI)
F1	0.979	1.005	0.982
F2	0.982	1.013	0.994
F3	0.886	1.089	0.967
F4	1.109	1.012	1.128
F5	1.308	1.130	1.358 (+35.8%)
F6	1.044	0.994	1.036
F7	0.798	1.133	0.879 (-12.1%)
F8	1.309	0.950	1.261
F9	0.997	0.995	0.993
F10	1.087	0.988	1.073
F11	1.195	1.181	1.313
F12	1.007	0.998	1.004
Average	1.058	1.041	1.082

comparing the values of the efficiency change and technique change indexes. Put it differently, the productivity losses described can be the result of either efficiency declines, or technique regresses, or both. Table 4 presents the results of these Malmquist productivity indices for 12 companies in years 2005 to 2008. For the companies as a whole, the average productivity change ranged from -12.1 (F7) to 35.8% (F5). F5 had the highest productivity growth from 2005 to 2008, followed by F11 and F8. From 2005 to 2008, there were seven companies with an average MPI, valued larger than one, which indicates the productivity growth in the period, the remaining five companies with an average MPI less than one, which indicates the productivity loss. In other words, seven companies improved their intellectual capital management efficiency whereas the other five companies failed to do that during the four-year period. Productivity loss for F1, F2, F3 and F7 was mainly caused by a decline of “catch-up” effect, the results indicate that the companies in the intellectual capital management, still have great room for improvement and need to reduce waste of input resources, to enhance the intellectual capital management performance. Conversely, productivity change loss for F9 was mainly caused by technological regression, the result indicates that the company needs the product innovation or technology development to enhance production technology.

For all of the observations, the average efficiency change and technique change were 5.8 and 4.1% respectively. Therefore in average, the productivity change is mainly due to improvement in technical efficiency rather than innovation in technology. As a whole, the productivity growth of Taiwanese pharmaceutical industry over the past four years is positive. Besides, efficiency change has more impact than technical change in terms of contribution to MPI improvement which induces a very important argument. MPI is very effective in identifying the importance of different enablers. However, both “catch-up” and “innovations” (“frontier-shift”) effects were predominately attributed to productivity growth.

This study adopts non-parametric statistics to further analyze the Taiwanese pharmaceutical industry. According to the classification of pharmaceutical company’s grade scale, this study discusses the diversity situation of pharmaceutical company’s productivity growth change in different scale grade. All companies are divided into three groups according to the number of employees; large, medium, and small scale according to number of employees, and also according to scale grade comparison of Malmquist productivity index, technical efficiency change and technical change.

We categorize an average of less than 200 employees as the small-scale companies, an average of 200 to 500 employees as the medium-scale companies, and an average of more than 500 employees as the large-scale companies. From Table 5, there are four companies for the small, medium and large scale respectively. The average number of employee is 105 for the small-scale companies, 249 for the medium-scale companies and 663 for the large-scale companies.

As shown in Table 5, the increment of the average of Malmquist productivity index from 2005 to 2008 was 8.6% for the large-scale companies, 6.5% for medium scale companies and 9.7% for small-scale companies respectively. The table shows that the speed of productivity growth of the small-scale companies is moderately faster than the large scale ones but much faster than the medium scale ones. The figures show that, the small-scale pharmaceutical factories paid much

Table 5. Decomposition of Malmquist index by size (2005 to 2008).

Size	N	No. of employee	Efficiency change	Technical change	MPI
Small	4	104.	1.102(0.15)	0.993(0.03)	1.097(0.13)
Medium	4	249	1.019(0.17)	1.074(0.10)	1.065(0.18)
Large	4	662	1.054(0.18)	1.054(0.07)	1.086(0.18)
Kruskal-Wallis x^2-test			0.694	0.694	0.794

attention to intellectual capital management in the past four years and tried to catch up. This observation confirms the conclusion made by Oluwajoba (2007) that SMEs (small and medium enterprises) need to increase the technological capabilities of the innovative company. The average of efficiency change from 2005 to 2008 was 10.2% for small-scale companies, 1.9% for medium-scale companies, and 5.4% for large-scale companies respectively. The catch-up speed of intellectual capital performance for the small-scale companies has faster progress than the large-scale and medium-scale. Obviously intellectual capital management of the small-scale pharmaceutical factory has big potential progress in the future. However, intellectual capital efficiency of the large-scale and medium-scale pharmaceutical factories has limited progress.

The average technical change from 2005 to 2008 was 5.4% for large-scale pharmaceutical companies, 7.4% for medium-scale companies and negative 0.7% for small-scale companies. As mentioned earlier, obviously the innovation effect of the medium-scale companies' technology is faster than the large-scale and small-scale companies.

According to the P-Value of Kruskal-Wallis test, the MPI indicates no significant difference among different scale groups, which means the productivity growth of Taiwanese pharmaceutical industry as a whole will not be affected by the size of companies. Moreover, the efficiency changes of different scale groups have no significant difference either, which shows the catch-up effect of the intellectual capital management performance of the industry as a whole will not be affected by the scale of companies. The technical changes indicate that the whole industry has no significant difference either, which means the technology will not be affected by the scale of companies even though the small-scale companies show negative trend.

Conclusions

Fast technology innovation has changed the business model tremendously. Intellectual capitals such as knowledge, collective expertise, brand value, human resources, innovation ability, patents, customer relationship and so on have played more and more important roles for a successful business (Aoki and Schiff, 2008). Many scholars and experts have already studied the related subjects of intellectual capital, which includes the meaning of intellectual capital, its elements and contents, and the stock measurement index. On the contrary, the study of intellectual capital management is still not sufficient so far.

In this study, we consider corporate intangible value and clearly understand intellectual capital management ability of each pharmaceutical company by GRA and DEA. The intellectual capital management performance is the key factor of high-tech companies' operation outcome, we hope those results can serve as precious reference for the academia and professionals. Concluding the results of data analyses, the main contribution of this study is presented as:

1. GRA has been a very flexible and easy tool to deal with decision-making problems, and DEA has long been an efficient analytical tool for profit and non-profit organizations, but little has been mentioned about the applications of GRA and MPI on knowledge-based industries, e.g. pharmaceutical companies. The research results presented here, thus provide very useful approach to probe the performance evaluation in information on this area.
2. The performance measurement via the application of GRA and MPI as shown in this work, including operational performance rankings, productivity evolution, provides meaningful implications of intellectual capital management. They are useful benchmarking tools, to examine the relative firm progress among competitors. Benchmarking parameters provide a meaningful reference to help firms improve their operating efficiency, speed up management change, set challenging goals, strengthen core competitiveness.
3. The research results suggest that intellectual capital, which comprises human capital, customer capital, and structural capital, is one of the main sources of competitive advantage for firms, specifically those technology-driven industries. This study argues that, intellectual capital is an essential strategic tool for use against competitors. The emphasis on intellectual capital can help firms implement new initiatives for enhancing their performance.
4. Pharmaceutical industry is one of the major industries in Taiwan. Measuring the operational performance of intellectual capital management and competitiveness of

pharmaceutical companies will enable such firms to examine whether they have managed these vital intangible assets efficiently. Additionally, pharmaceutical permission, intellectual property, influence the successes or failure of pharmaceutical companies significantly.

According to the research result and the courses of the research, there are some suggestions for further studies:

1. DEA is a sensitive tool. Before using it, defining DMU clearly and choosing inputs and outputs very thoroughly are necessary. Furthermore, MPI is a very useful tool to conduct the measurement of performance indicator as well as identify the importance of key success factors to the performance indicator. Industry management always focuses the performance measurement. Because there will be no management if there is no measurement. Therefore, many models of DEA are widely used in industry application;
2. Wider range of variables of input and output can be studied such as number of patents, the ratio of R&D expenditure or number of research employees (Wu et al., 2006). Some other high-tech industries can be assessed by this proposed model in future research, such as LED manufacturing, biochemical industries, and so on.

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