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專利績效、研發能力與員工生產力對公司績效之正向影響

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摘要

本研究探討專利績效、研發能力與員工生產力對公司績效之影響。本研究使用專利密集度、最重要技術領域之技術優勢與員工平均產出作為美國化工業專利績效、研發能力與員工生產力的代理變數。研究結果顯示專利密集度、最重要技術領域之技術優勢與員工平均產出會正向影響公司績效。因此，本研究證實專利密集度、最重要技術領域之技術優勢與員工平均產出是公司績效的正向驅動因子。因此公司想要提升公司績效的話，應該提高其專利密集度、最重要技術領域之技術優勢與員工平均產出。

本文

目的

PICMET 2011 Conference是科技管理領域最重要的年度學術研討會，每年有許多國際級管理大師參加PICMET Annual Conference，而且PICMET 2011 Conference主辦單位也邀請許多全球資深管理學者評審論文，並當場給予論文報告人許多寶貴建議。雖然投稿PICMETAnnual Conference的接受率極低，但是只要被PICMET Annual Conference接受的論文，能依照論文評論者的建議加以修改的話，轉投SSCI期刊的接受率將會大幅提高。因此，PICMET AnnualConference是全球科技管理學者最期盼的年度學術研討會。參加本次研討會可以提升本人研究能力，增加國際視野，並提高國際期刊發表能力。

過程

本人非常榮幸出席知名國際研討會 Portland International Center for Management of Engineering and Technology (PICMET) 2011 Conference（地點：Hilton Portland and Executive Tower, Portland, Oregon, USA，Room: Council Suite，場次：ME-08），並發表論文。本場次共有三位發表人，除了本人之外，其他二位發表人分別為：Dr. Yvonne Siwczyk、Dr. Kunio Shirahada。本人的論文係探討專利績效、研發能力與員工生產力對公司績效之正向影響，研究結果發現專利績效、研發能力與員工生產力對公司績效有顯著正向影響。Dr. Yvonne Siwczyk 所報告的文章則是以專利資訊探討企業的研發技術所處的位置，並藉此來確認競爭者與合作夥伴所處之位置，並尋找研發機會。Dr. Kunio Shirahada 則探討研發人員使用試誤法解決問題之過程，並探討影響之組織因素。此外，與會學者對於本人發表之研究也提出批評，數人建議研究樣本除了美國化工產業之外，後續研究可挑選其他產業的公司進行分析，並進行跨產業比較。此外，本研討會的主持人 Dr. Brent Dixon 教授也對本論文提出許多寶貴建議，尤其對於文章的管理意涵的不足之處提出具體批評，而且建議後續應再補強專家訪談，以支持本文之論點。參與本次研討會獲得許多寶貴的建議，尤其本研討會的主持人 Dr. Brent Dixon 教授非常欣賞本文章，他建議該文章可以參考多位學者的評論與建議而加以修改與補強之後，可以進一步投稿國外知名期刊。本次研討會行程參加至 100 年 8 月 3 日止，其他行程則於 100 年 8 月 4 日起至 8 月 8 日止轉赴洛杉磯參訪洛杉磯大學 Irvine 校區，與相關學者進行學術交流，以瞭解美國高科技產業發展現況，並詢問相關學者有關本研討會論文後續修改建議。

心得及建議事項

參與本次國際研討會除了提高個人的國際視野之外，並能與世界各國科技管理領域的學者交換研究心得，獲得許多寶貴的研究經驗。此外，透過本次國際研討會也認識了不少國際知名的研究學者，回國後希望能繼續向這幾位國際知名研究學者請益，並期盼日後能有跨國共同研究的機會。參與本次國際研討會並發表文章實在是收獲非常多，而且非常感謝行政院國科會的補助。本人在此並無其他建議，而且希望明年再次爭取行政院國科會補助出席國際研討會。

（附錄）

論文全文檔

The Positive Effects of Patent Performance, R&D Capability, and Employee Productivity on Firm Performance

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Abstract. This paper explores the influences of patent performance, R&D capability, and employee productivity upon firm performance. This study uses patent intensity, revealed technology advantage in the most important technological field (RTA_{MIT}), and average output per employee as the proxy variables of patent performance, R&D capability, and employee productivity in the American chemical industry. The results indicate that patent intensity, RTA_{MIT}, and average output per employee of firms are positively associated with their performance. This study verifies that patent performance, R&D capability, and employee productivity positively affect firm performance.

Keywords: Patent Performance, R&D Capability, Employee Productivity, Firm Performance, Resource-Based View

I. INTRODUCTION

The chemical industry is crucial to the modern economy in the world, converting raw materials (oil, natural gas, air, water, metals, minerals, etc.) into more than 70,000 different products [47]. Chemicals are used to make a wide variety of thousands inputs into agriculture, manufacturing, construction, and consumer goods. The major industrial customers of the chemical industry include rubber and plastics, textiles, apparel, petroleum refining, pulp and paper, and metal companies. This study is conducted in the American chemical industry. The chemical industry is concentrated in three areas in the world: North America, Western Europe, and Japan [47]. The American chemical industry earns large trade surpluses and employs more than a million people in the United States. The American chemical market generated gross output of $638.4 billion dollars in 2008, and its compound annual growth rate (CAGR) of 2001-2008 was 7.17% [47]. Besides, the American chemical market generated value added of $212.8 billion dollars in 2008, and its compound annual growth rate (CAGR) of 2001-2008 was 5.56% [47]. In addition, the American chemical market generated gross operating surplus of $118.9 billion dollars in 2008, and its compound annual growth rate (CAGR) of 2001-2008 was 8.42% [47]. Hence, the American chemical industry displayed its steady growth during the past years.

Under new economy era, intangible assets become an important determinant for competitive advantage of firms [13]. The value of a firm is equal to its tangible assets plus its

intangible assets [30]. However, in the era of knowledge economy, firms' intangible assets are often greater than their tangible assets [13]. Because of the raise of intangible assets in industries, the gap between market value and book value of firms has been increasing continuously; consequently, the real value of a firm is no longer correct on its financial statements [13]. Traditional accounting systems can no longer correctly express the market value of a firm nowadays, so the evaluation of firm's real value should shift from the previous evaluation of tangible assets to the expression of intangible assets [10]. This study was conducted in the chemical industry of US. Prior studies claimed patents play a more important role in protecting firms' R&D outcomes in some industries (e.g., the chemical and pharmaceutical industries) than in others (e.g., the motor vehicles, rubber, and textiles industries) [4, 12]. The reason that this study pays attention on the American chemical industry is because US is the largest single market in the world, and thus most of companies seek to patent their technologies in US. Besides, US is one of the important countries for the chemical industry in the world. The chemical industry is chosen because it is highly technology-based and thereby places heavy emphasis on R&D. Therefore, this research selected the American chemical industry as the research object.

Because companies pay more attention to the accumulation of intangible assets nowadays [42], different intangible assets which include intellectual property, capability, human capital, etc., become an essential strategic weapon nowadays. Therefore, intangible

assets are very important for firm performance. In addition, intangible assets are usually more difficult to imitate than tangible assets, so competitive advantages of firms are less obtained from the allocation of tangible assets, and more from intangible assets according to resource-based view (RBV) [2]. This study employs a pilot study to interview eight experts in the chemical industry and finds out the key intangible assets in this industry are patents, R&D capability, and human capital. There are some prior studies discussing about the influence of intangible assets upon performance of firms [42], but there is no literature which explores this influence from the three types of intangible assets - patents, R&D capability, and human capital. Therefore, this study explores the relationship between the performance of the three types of intangible assets and performance in the American chemical industry to fill the research gap.

The purpose of this paper is to investigate the influence of the performance of the three types of intangible assets - patents, R&D capability, and human capital - upon firm performance in the American chemical industry. This study utilizes patent intensity as the proxy variable of patent performance, revealed technology advantage in the most important technological field (RTA_{MIT}) as the proxy variable of R&D capability, and employee productivity (sales-per-employee ratio) as the proxy variable of human capital. Therefore, the explanatory variables are patent intensity, RTA_{MIT}, and employee productivity, while the dependent variable is firm performance in the panel data model. This paper is structured as

follows: this study presents the literature review, and then derives the research hypothesis in section 2. In section 3, this study describes the methodology and measurement. In addition, this study also defines patent and financial indicators to explore the statistical analysis. In section 4, this study demonstrates the empirical results. In the last section, this study presents the discussion and conclusion, and proposes some managerial implications and suggestions.

II. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

A. Resource-Based View (RBV) and the Importance of Intangible Assets

Resource-based view (RBV) is a management approach used to determine the strategic resources available to firms. Resources of companies include physical assets, capabilities, organizational culture, patents, trademarks, human capital, etc [15]. The principle of RBV is that the basis for a competitive advantage of a firm lies primarily in the application of the bundle of valuable resources at the firm's disposal [48]. To transform a short-run competitive advantage into a sustained competitive advantage requires that these resources are heterogeneous in nature and not perfectly mobile [1, 38]. According to RBV, companies within an industry may be heterogeneous with the respect to the strategic resources they control. There are four indicators to measure the potential of resources to generate sustainable competitive advantage – value, rareness, inimitability, and non-substitutability [1].

If a company obtains valuable, rare, resources, inimitable, and non-substitutable resources, it can exploit those resources in implementing value-creating strategies to obtain sustainable competitive advantages, because these resources may not be perfectly mobile across companies and thus heterogeneity can be long lasting [1]. If value, rareness, inimitability, and non-substitutability are the characteristics of resources of companies, they are helpful to innovation and companies can exploit them to gain competitive advantages [39].

In the era of knowledge economy, intangible assets are usually more costly to imitate than tangible assets, so competitive advantages of firms are less based on the allocation of tangible assets, and more on intangible assets, such as patents, R&D capabilities, and human capital [2]. Although patents, R&D capabilities, and human capital are intangible and their value cannot be accurately measured, companies must develop and increase their performance by proactively focusing on them. The disparity between the book value of publicly traded companies and their market value has increased steadily in recent years [34]. Breitzman and Thomas [8] thought that the substantial value of intangible assets is not accounted for on the financial statements of most companies. Thus, the information provided in annual reports about innovative activities is inadequate and the information about intangible assets is so limited in financial statements [20]. Estimating the firm performance based on the patents, R&D capabilities, and human capital may therefore provide insights into the value of companies' intangible assets [11]. Therefore, recent researches with regard

to intangible assets have drawn much attention recently on how to evaluate the real value of firms [45], and this study investigates the relationship between the performance of three types of intangible assets - patents, R&D capabilities, and human capital - and firm performance.

B. The Influence of Patent Intensity upon Firm Performance

Innovation is a key source of competitive advantage nowadays [40]. Continuous innovation over time may enable firms to continue to generate high levels of performance [41]. If firms do not engage in innovation would cause the competitiveness of products to be eliminated, the market position would be robbed by more creative rivals [35]. Thus, innovation is the key for enterprises to seek survive and grow. Previous studies found out that innovation performance of a firm had a significantly positive impact on its performance [7]. Patents are one of important innovation outcomes, since they may allow the innovator to earn monopoly profits [43]. Hence, patent performance is one measure of innovation performance of firms [28, 46]. In addition, patents are seen as important intangible assets, and patent information can help us trace the technological development of companies [36]. Patents data have the principal benefit because patent data are more likely to be related to innovation output than R&D data and are available for a far longer time span than R&D data [14]. Ernst [18] claimed patent information can be used in three important areas: first, analyzing patent

information can provide relevant information about competitors' R&D strategies and potential competitive technologies; second, patent information can be used to identify and to assess options for the external sources of technological knowledge [23]; third, patent information can be used as a tool for knowledge management and human resource management in R&D [19]. Therefore, in comparison with other information, patent information is often considered to be the best source for the timely recognition of technological innovation of firms [9].

When products are patented, the ability of competitors to imitate them may be significantly delayed, and therefore the original innovator can increase revenues and earn more profits [11]. Prior studies showed that there is a positive relationship between patent performance and firm performance, because patent rights can not only protect their intellectual property but also license to other companies and increase the occupation of market share [12, 24, 27]. Besides, according to resource-based view (RBV), developing patents is path-dependence and patents can be protected by intellectual property right so that it is hard to imitate patents which eventually play an important role for firms' competitive advantage and superior performance [2]. This study uses patent intensity as the proxy variable of patent performance and explores its influence upon firm performance. Hence, this study proposes the following hypothesis:

Hypothesis 1 (H_1): Patent intensity of firms is positively related to their performance.

C. The Influence of Revealed Technology Advantage (RTA) upon Firm Performance

Previous studies asserted R&D of firms can create new knowledge, products, or new processes, reduce operation and manufacture cost, and enhance competitive advantages, and argued that there is a positive relationship between R&D capability and firm performance [29]. This study utilizes revealed technology advantage in the most important technological field (RTA_{MIT}) as the proxy variable of R&D capability. Soete and Wyatt [44] defined the revealed technology advantage (RTA) as an organization's advantage in one particular technological field compared to other organizations. Revealed technology advantage (RTA) for various countries is used in calculation as a country's share of US patenting in one sector divided by the country's share in all patenting sectors [21, 44]. Therefore, the RTA is a wide-used measure for technological advantage. Patel and Pavitt [37] also used RTA to measure and to classify firms' technological competencies, and they argued the higher RTA of a firm, the stronger is its relative strength in one particular technological field. Therefore, RTA can measure the R&D capability in the particular technological field for companies. It means a firm's share of patenting in one particular technological field divided by all firms' aggregate share of patenting in all fields.

Chen and Chang [12] defined the most important technological field of a firm as it has more patents in the field than in other technological fields. Revealed technology advantage in

a firm's most important technological field (RTA_{MIT}) is a firm's share of patenting in the technological field where it has more patents than in other technological fields divided by all firms' aggregate share of patenting in all fields [12]. If a firm's RTA_{MIT} is higher, the firm is considered to have more R&D capability in its most important technological field. Opposite, if a firm's RTA_{MIT} is lower, the firm is considered to have less R&D capability in its most important technological field. The higher RTA_{MIT} of a firm, the stronger is its R&D capability in the particular technological field. Furthermore, the stronger the R&D capability of a firm in its most important technological field, the better is its performance. In addition, based on resource-based view (RBV), generating R&D capability is path-dependence and R&D knowledge is tacit such that it is difficult to imitate R&D capability which consequently plays an important role for firms' competitive advantage and superior performance [2]. Thus, this study proposes the following hypothesis:

Hypothesis 2 (H_2): Revealed technology advantage of firms in their most important technological fields (RTA_{MIT}) is positively related to their performance.

D. The Influence of Employee Productivity upon Firm Performance

Human capital is one of an organization's intangible assets, and it is the accumulation of the competencies and commitments of the employees within an organization, i.e. their skills,

experience, potential, and capabilities [5, 6]. In addition, because human capital is the stock of productive skills and technical knowledge embodied within employees, human capital of a firm is positively associated with its performance [5, 31, 33]. In the era of the knowledge economy, human capital is companies' critical assets. Bartel [3] indicated that companies' return on investments in employees' training may be much higher than previously believed. Hence, prior studies posited that investments of human capital would positively affect firm performance [3, 5]. The impact of human capital may occur in two ways: a knowledgeable workforce may directly increase business performance; and a skilled workforce may indirectly act as a complement to improved technologies, business models, or organizational practices [5, 6]. de Grip and Sieben [16] argued that training employees is an adequate approach to increase human capital, since it increases performance without affecting the average wage level. Besides, Huselid [26] indicated that the performance of employees influences firm performance.

In economics, productivity is the amount of output created (in terms of goods produced or services rendered) per unit input used. For example, employee productivity is typically measured as output per employee. This study defines employee productivity as the "average output per employee (sales-per-employee ratio)". This study applies employee productivity as the proxy variable of human capital. Black and Lynch [5] pointed out that human capital investments would positively influence firm performance. Furthermore, according to

resource-based view (RBV), building human capital is path-dependence and human capital is unobservable so that it is costly to imitate human capital which thereby plays an important role for firms' competitive advantage and superior performance [2]. Therefore, this study postulates that the employee productivity of a firm would affect its performance positively, and proposes the following hypothesis:

Hypothesis 3 (H_3): Employee productivity of firms is positively related to their performance.

Based on resource-based view (RBV), building intangible assets is path-dependence and it is not easy to imitate intangible assets such that intangible assets become an important determinant for firms' competitive advantage and superior performance [2]. According to the in-depth interviews with eight experts in the chemical industry, this study figures out patents, R&D capability, and human capital are three key intangible assets in the chemical industry. This study uses patent intensity, RTA_{MIT}, and employee productivity as the proxy variables of the performance of the three key intangible assets in the chemical industry. Hence, this study verifies the three hypotheses by exploring the influences of patent intensity, RTA_{MIT}, and employee productivity of firms upon their performance. The research framework of this study is shown in Fig. 1.

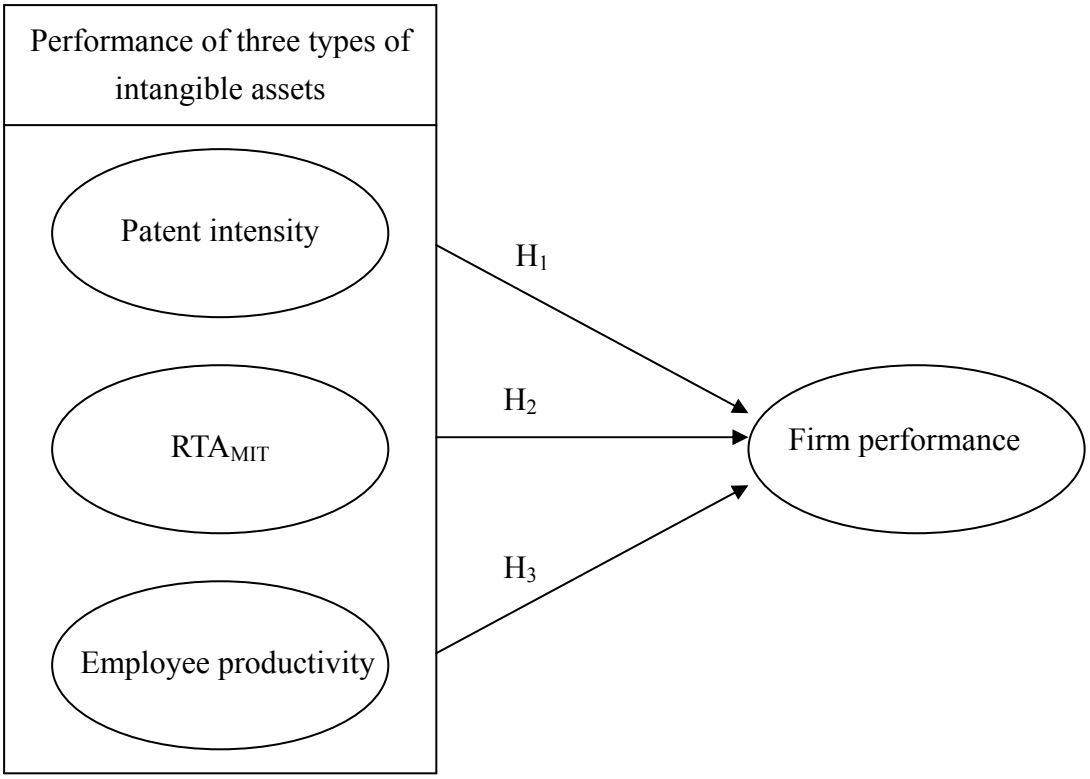

Fig. 1. Research framework

III. METHODOLOGY AND MEASUREMENT

A. Sample and Data Collection

This research is conducted in the American chemical industry. The financial data of this study are obtained from the COMPUSTAT database. The COMPUSTAT database contains the financial data of publicly traded companies in US. The sample of this study is collected from COMPUSTAT through the Global Industry Classification Standard (GICS) to search the American chemical companies. There are 91 American chemical companies in the sample, and their GICS is 1510. The panel data in this study including patent data and financial data

span the period from 2004 to 2009. Hence, the sample size of the panel data in this study was 546. Panel data combining the longitudinal and cross-sectional characteristics may have firm-specific effects, period-specific effects, or both. In order to analyze the panel data, this study applies panel data model to verify the hypotheses in the research framework. The patent data of this study is gathered from the United States Patent and Trademark Office (USPTO). The patent data of this study have sufficient information about names of assignees, technical fields, the issued dates, and so on, form 1974 to 2009. Patel and Pavitt [37] used the technological fields of U.S. patenting as the basic units of competence to measure a combination of corporate competencies in the different technological fields. In addition, they argued that the granting of a patent reflects that the assignee has the R&D competence in the technological filed significantly. That's why this study chose the UPC (US patent classification) to measure R&D capability in the different technological fields. By tracking the UPC classifications of patents and their distribution across technology areas, we can monitor and compare the evolution of companies' R&D activities through different technological fields. We can identify R&D capability of companies year by year.

B. Measurement

Firm performance. The dependent variable of this study is firm performance. This study utilizes the "total asset turnover ratio" as the proxy variable of firm performance. The total

asset turnover ratio measures the ability of a company to use its assets to generate sales. Higher this ratio, the smaller the investment required to generate sales and, therefore, higher performance of the firm. This study acquired the total asset turnover ratio of the American chemical companies from COMPUSTAT. "The total asset turnover ratio" is defined as output per unit assets employed, and it is calculated as follows:

$$\text{Total asset turnover ratio} = \text{Sales} / \text{Total assets}$$

Patent intensity. This study uses patent intensity as the proxy variable of patent performance. Patent intensity is the ratio of annual new granted patent counts to total assets. By tracking companies' patent intensity, we can monitor their patent performance [17]. According to Erdogan [17], patent intensity is calculated as follows:

$$\text{Patent intensity} = \text{Annual new granted patent counts} / \text{Total assets}$$

Revealed technology advantage in the most important technological field (RTA_{MIT}). This study utilizes revealed technology advantage in the most important technological field (RTA_{MIT}) as the proxy variable of R&D capability. Revealed technology advantage (RTA) is a firm's share of patenting in one particular technological field divided by all firms' aggregate share of patenting in all fields [44]. RTA can measure firms' technological competence in one particular technological field compared to others, and the higher RTA of a firm, the stronger is its relative strength in the particular technological field [37]. The most important technological field of a firm is defined as it has more patents in the field than in

other technological fields [12]. Revealed technology advantage in a firm's most important technological field (RTA_{MIT}) is a firm's share of patenting in the technological field where it has more patents than in other technological fields divided by all firms' aggregate share of patenting in all fields [12]. If a firm's RTA_{MIT} is higher, the firm is considered to have more R&D capability in its most important technological field. The revealed technology advantage in a firm's most important technological field (RTA_{MIT}) is calculated as follows:

$$RTA_{MIT} = \frac{P_{kg} \Big/ \sum_i P_{ig}}{\sum_j P_{kj} \Big/ \sum_i \sum_j P_{ij}}$$

where P_{kg} means the patent counts of the focal company g in its most important technological field k; $\sum_i P_{ig}$ means the patents counts of the focal company g in all technological fields; $\sum_j P_{kj}$ means the patents counts of all companies in its most important technological field k; and $\sum_i \sum_j Pij$ means the patents counts of all companies in all technological fields.

Employee productivity. This study applies employee productivity (sales-per-employee ratio) as the proxy variable of human capital. This study defines "employee productivity" as the "average output per employee", and it is calculated as follows:

Employee productivity = Sales / Number of employees

IV. EMPIRICAL RESULTS

Table 1 shows the descriptive statistics of this study. The panel data of this study including patent data and financial data are collected from 2004 to 2009. In order to analyze the panel data, this study utilizes panel data model to verify the hypotheses in the research framework. Panel data containing the longitudinal and cross-sectional characteristics may have firm-specific effects, period-specific effects, or both. There are three types of panel data models: pooled regression model, fixed effect model, and random effect model [22]. Solutions to the problems of heterogeneity and autocorrelation are of interest among these three types of panel data models. Both intercepts and slopes of the pooled regression model have constant coefficients. In the pooled regression model that has neither a significant firm-specific effect nor a period-specific effect, we could pool all of the data and run an OLS regression model [25]. Although there are often either firm-specific effects or period-specific effects, there are some occasions when both firm-specific effects and period-specific effects are not statistically significant. The fixed effect model assumes there are differences in intercepts across firms or periods, whereas the random effect model explores differences in error variances. The fixed effect model, also known as least square dummy variable (LSDV), removes all between-firm variance and thus controls for any time invariant unobserved heterogeneity among firms. Hence, the fixed effect model constrains the coefficients to be

within-firm effects [32]. The random effect model considers the firm-specific effects as random variables, and it assumes that firm-specific effects are normally distributed throughout the population [22].

Table 1. Descriptive statistics

	Mean	Standard Deviation	A.	B.	C.
A. Firm performance	0.978	0.421			
B. Patent intensity	0.033	0.056	0.249*		
C. RTA_{MIT}	258.16	738.53	0.275**	0.107	
D. Employee productivity	398.68	229.72	0.413**	0.042	0.033

Note: ** significant at the 1% level; * significant at the 5% level.

There are two stages to determine which panel data models should be selected in this study. First, this study applies Breusch-Pagan test (LM test) to determine the pooled regression model or the random effect model should be selected as the empirical model [22]. The result shows that the random effect model is better than the pooled regression model in Table 2. Second, this study uses Hausman test to determine the fixed effect model or the random effect model should be selected as the empirical model [22]. The result demonstrates that the random effect model is better than the fixed effect model in Table 2. Therefore, this study utilizes the random effect model to verify the hypotheses in the research framework. This study reports the results of Breusch-Pagan test (LM test), Hausman test, and the random effect model in Table 2.

The dependent variable of the panel data models in this study is firm performance, and the explanatory variables are patent intensity, RTA_{MIT}, and employee productivity. This study applies the random effect model to test the hypotheses, and the result is shown in Table 2. Table 2 indicates that patent intensity is positively associated with firm performance. Hence, the hypothesis H_1 is supported in this study. It means that the more patent intensity of a firm, the better is its performance. Moreover, Table 2 shows that RTA_{MIT} is positively associated with firm performance. It means that the more a firm's RTA_{MIT}, the better is its performance. Hence, the hypothesis H_2 is supported in this study. Furthermore, Table 2 demonstrates that employee productivity is positively associated with firm performance. Hence, the hypothesis H_3 is significantly supported in this study. It means that the more a firm's employee productivity, the better is its performance.

The positive relationship between patent intensity and firm performance means that enhancing companies' patent intensity can increase their performance. Therefore, American chemical companies should enhance their patent intensity to increase their patent performance and eventually to raise their performance. Besides, the positive relationship between RTA_{MIT} and firm performance means enhancing a company's R&D capability in its most important technological field can increase its performance. If RTA_{MIT} of a company is higher, it has more R&D capability in its most important technological field. Because the R&D investments of the chemical industry are very expensive, the R&D competition

between chemical companies is quite intense. Therefore, American chemical companies should raise their RTA_{MIT} to enhance their R&D capability in order to obtain technological advantages if they want to increase their performance. In addition, the positive relationship between employee productivity and firm performance means enhancing employee productivity of companies in the chemical industry is beneficial for their performance. If companies have higher employee productivity, their human capital and average output per employee would be better such that they can raise their performance.

Table 2. Empirical results of panel data model (random effect model)

	Random Effect Model
Dependent Variable: Firm performance	
Intercept	0.577**
	(7.609)
Independent Variables	
Patent intensity	0.355*
	(1.972)
RTA_{MIT}	0.0003**
	(3.354)
Employee productivity	0.0007**
	(3.868)
F-Value	56.437**
P-Value	0.001
R^2	0.406
Adjusted R^2	0.399
Breusch-Pagan test (LM test)	398.32**
Hausman test	0.45

Note: ** Significant at the 1% level; * significant at the 5% level. The data in the parenthesis is t-value. The panel data span the period from 2004 to 2009. There are two stages to determine which panel data models should be selected in this study. (1) Breusch-Pagan test (LM test): Pooled Regression Model vs. Random Effect Model. H_0: Var (u)=0. $\chi^2_{(1)}$=398.32 → Reject H_0, and select Random Effect Model. (2) Hausman

test: Fixed Effect Model vs. Random Effect Model. H_0: Differences in coefficients are not systematic. $\chi^2_{(3)}= 0.45 \rightarrow$ Not reject H_0 , and select Random Effect Model.

V. CONCLUSION AND IMPLICATIONS

Based on resource-based view (RBV), intangible assets are usually harder to imitate than tangible assets, so companies obtain competitive advantage less from the deployment of tangible assets, and more from intangible assets. The aim of this paper is to discuss the relationship between the performance of different intangible assets and firm performance. This study conducts a pilot study to interview eight experts in the chemical industry and demonstrates that the key intangible assets in this industry are patents, R&D capability, and human capital. This study uses patent intensity, revealed technology advantage in the most important technological field (RTA_{MIT}), and employee productivity (sales-per-employee ratio) as the proxy variables of patent performance, R&D capability, and human capital. The dependent variable of this research is firm performance, while the independent variables are patent intensity, RTA_{MIT}, and employee productivity. The results indicate that patent intensity, RTA_{MIT}, and employee productivity of firms are positively related to their performance. In the era of the knowledge economy nowadays, successful chemical companies must pay more attention on the three types of intangible assets - patents, R&D capability, and human capital. Enhancing intangible assets can raise firm performance in the chemical industry. Therefore,

if American chemical companies want to enhance their performance, they should enhance their patent intensity, RTA_{MIT}, and employee productivity.

There are several interesting findings in this study. First, this study addresses that American chemical companies' patent intensity is positively related to their performance. Hence, this study suggests American chemical companies need to enhance their patent intensity to raise their patent performance and eventually to increase their performance. Second, the results in this research show that American chemical companies' RTA_{MIT} is positively related to their performance. If RTA_{MIT} of a company is higher, it has more R&D capability and technological advantage in its most important technological field. Because the R&D investments of the chemical industry are very vast, the R&D competition in the chemical industry is quite fierce. Thus, this study suggests chemical companies must enhance their RTA_{MIT} to increase their R&D capability and technological advantages if they need to raise their performance.

Third, the results in this research point out that American chemical companies' employee productivity is positively related to their performance. If chemical companies have better employee productivity, their human capital and average output per employee would be more outstanding such that they have better firm performance. Therefore, if chemical companies need to increase their performance, this study suggests they should enhance their employee productivity. Fourth, facing the rise of raw material and energy costs and the

stagnation in the American market, many chemical companies try to divest less profitable businesses in order to concentrate on their core businesses. However, according to the results of this study, American chemical companies can improve their patent intensity, RTA_{MIT}, and employee productivity to enhance their profit margin when they face the rise of raw material and energy costs and the stagnation in the American market. Fifth, this study undertakes a pilot study to interview eight experts in the chemical industry and demonstrates that the key intangible assets in this industry are patents, R&D capability, and human capital. The quantitative empirical results of the panel data model support the qualitative interview results of the pilot study.

This research is conducted in the American chemical industry. Future studies can focus on other industries to explore the relevant topics, and compare to this study. Moreover, this study explores the influence of the performance of the three types of intangible assets - patents, R&D capability, and human capital upon firm performance. Future studies can focus on the performance of other types of intangible assets to explore the relevant topics, and compare to this study. Finally, this study hopes that the research results can be useful for managers, researchers, or policy makers, and contribute to relevant studies and future researches as reference.

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