CSCanada
International Business and Management
Vol. 9, No. 2, 2014, pp. 62-69
DOI:10.3968/5602

ISSN 1923-841X [Print]
ISSN 1923-8428 [Online]
www.cscanada.net
www.cscanada.org

The Intellectual Capital and Technology Innovation Performance—Empirical Study Based on Universities Affiliated with Ministry of Education

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Received 8 July 2014; accepted 5 September 2014
Published online 30 November 2014

Abstract

This paper aims to explore the mechanism of university intellectual capital on the performance of technology innovation of university by empirical research. On the base of theoretical analysis between the human capital, structure capital and relationship capital of university intellectual capital as well as its role on the performance of technology innovation, six hypotheses were proposed and a conceptual model was build. 19 indicators data from 2009 to 2013 of 64 universities was selected. It concluded that human capital has a positive impact on both structure capital and relationship capital, meanwhile, structure capital also has a significant effect on the relationship capital. It also found that human capital and relationship capital could positively affect the performance of university technology innovation directly, both structure capital and human capital have positive impact on innovation performance by relationship capital as mediator.

Key words: University; Intellectual capital; Innovation performance

Zhang, Y. H., & Cao, H. (2014). The Intellectual Capital and Technology Innovation Performance—Empirical Study Based on Universities Affiliated with Ministry of Education. *International Business and Management, 9*(2), 62-69. Available from: http://www.cscanada.net/index.php/ibm/article/view/5602
DOI: http://dx.doi.org/10.3968/5602

INTRODUCTION

Twenty-first century, the information technology developed quickly, global economic competition continues to intensify, society has entered the era of the knowledge economy from the industrial economy. Knowledge replaces the traditional factors of production labor, capital and land has become the most important resource, we are moving away from labor-intensive and resource-intensive era, gradually entered the era of knowledge-intensive. In the trends of knowledge economy, innovation has become the origin of competitive strength. Technology innovation is a manifestation of national strength and competitiveness, the level of technology innovation determines the political and economic position of country in the world, universities as base of knowledge production, is playing the role of the main force of technology innovation.

Researches on intellectual capital initially concentrated in the enterprise, and then gradually extended to regional and other organizations, the researches on university intellectual capital theory are gradually deepening and enriching. As Goran Roos think that compared to corporate and other for-profit organizations, intellectual capital theories are more suited to public institutions, public sector and other non-profit organizations (Jiang, 2011). More and more scholars have tried a new perspective and applied new methods to prove intellectual capital can promote the enterprise performance, but whether the university intellectual capital can also promote technology innovation performance of university remains a serious problem.

The concept of intellectual capital is still having no uniform understanding. Based on the current research, it can be summarized as the following three aspects: The first is the knowledge and ability, which is from the perspective of knowledge and ability to understand the intellectual capital (Bontis, 2001). The second is intangible assets, this view thinks that intangible assets

considered as intellectual capital (Mason, 2009). The third is value, which is believed that intellectual capital is the part value exceeded book of the company (Kaarst-Brown, 2003). Based on the universities' characters of non-fully profit and semi-public service, we choose the first one to define the university intellectual capital. University intellectual capital refers to itself owned, which meets the requirements of the university's development strategy, to achieve the three functions of personnel training, scientific research and social services, reflecting the potential strength and the future development of the university.

There are also three ways to divided intellectual capital, which is divided in two parts, three parts and four parts, and divided in three parts is a common way, Stewart (1994) is the earliest scholar who divided intellectual capital into three dimensions known as "H-S-C" structure including human capital, structure capital and customer Capital. Edvisson and Sulllvan (1997) divided intellectual capital into human resources and structure capital. Mark (1999) first proposed the four dimensions division from a new perspective, on the three dimensions of human capital, structure capital and customer capital increased innovation capital. This paper follows the majority of scholars to divide the university intellectual capital into human capital, structure capital and relationship capital three dimensions. University's human capital is the knowledge and skills, which can create value, belong to university teachers, students and research staff. University's structure capital refers to the knowledge and experience which already exists in the university database, patents, manuals and system processes, which has been institutionalized, including infrastructure, regulations, campus culture, libraries and all university assets, etc. University's relationship capital is the knowledge which dependent on the relationship between individuals and their network, including academic exchanges, cooperation with foreign and universities reputation, etc.

The research about university intellectual capital started late, but it has now attracted the attention of a growing number of scholars, Khalkhali, Shakibaei and Khodadoost (2012) designed a model that can determine and manage the intellectual capital of the education system in Iran. He selected 500 education experts to confirm the integral part of intellectual capital of educational system by filling out the questionnaire and finally get five key factors affecting the education system of intellectual capital. Victor, Adriana and Juan (2012) analyzed the publication of Columbia University from 1958 to 2008 and described the link between growth trends of production of knowledge and intellectual capital accumulation. Zhu and Guan (2007) constructed university intellectual capital model through questionnaires. The study shows that there is a positive relationship between the three constituent elements of intellectual capital. Xu and Shao (2009) believe that intellectual capital is the core competitiveness of organization, while university intellectual capital model should include human capital, structure capital, leadership capital and social capital. On this basis, they proposed a cycle of university management. Jiang (2012) analyzed how university intellectual capital affect university research and innovation capacity. He use trend surface analysis to classify the university and proposed suggestions to enhance the university research and innovation capacity.

Throughout existing research, most scholars focus on the content and structure as well as the factors of university intellectual capital. They discussed some suggestions to enhance university research and innovation capacity and technology innovation performance. But the empirical study combining university intellectual capital and university innovation is still relatively little. In fact, to correct answer what effect intellectual capital on technology innovation, the premise is to clarify the relationship between the three dimensions of intellectual capital. The existing studies ignore this, even if there is, it is more common for qualitative analysis, quantitative analysis is lacking.

1. THEORETICAL ANALYSIS AND HYPOTHESIS

The relationship between the three elements of university intellectual capital has been a research focus, as Ferec Cetni (2000) thought that any element of an interaction between intellectual capital alone is meaningless. The value comes from the three (Li & Huang, 2003). Bontis's (1998) and Bontis's et al. (2000) empirical research shows that there is a correlation between human capital, structure capital and relationship capital. It shows that the relationship between the three are mutually reinforcing and inseparable.

Knowledge and attitude of all categories of personnel of universities gathered together is the campus culture, which is embedded in the process of teaching and research in universities, undergoing a subtle influence. The reason for developing the structure capital is in order to get workers' knowledge together, because only solidified into a structure capital can face the external challenges. Playing the role of human capital is attached to the structure capital. structure capital is an important foundation of university technology innovation. Kaplan & Norton's (1996) study shows that when employees perform internal processes, also convey the quality of services to outside, so the pros and cons of staff's performance will affect the quality of internal processes and corporate services. Tseng's (2005) study found that high employee satisfaction contributes to the exchange of information within the organization, and thus can help organizations to establish more effective operational processes. It is likely, therefore, that a positive relationship

exists between human capital and structure capital. This results in the following hypothesis:

H1: Human capital has a positive impact on structure capital.

Conceptually, the relationship capital is the knowledge which dependent on the individual and their network. Establish and maintain such relationship requires the cooperation and support of human capital. A high level of staff quality and social skills (high levels of human capital) can introduce and retain more external capital (relationship capital) for the organization, and create a more harmonious and cooperative relations. Highly qualified teachers, students and researchers have more opportunities to participate in various academic exchanges and cooperation with foreign countries. They also will promote the improvement of the reputation of universities, and expand students and so on. Bontis (2000) pointed out, no matter what industry, the more stronger the ability of employees, the more they understand customer needs, the more customer capital they can develop to maintain customer's loyalty. It is likely, therefore, that a positive relationship exists between human capital and relationship capital. This results in the following hypothesis:

H2: Human capital has a positive impact on relationship capital.

Creating and maintaining relationship capital needs socialization skills and organizational culture of structure capital. Meanwhile, structure capital can facilitate communication between members of the social network, providing the tools needed to solve the population problem. University's strong academic atmosphere, rich learning resources, teaching facilities (high level of structure capital) help the school form a good reputation, expand communication networks and improve university relationship capital. Bontis (2000) pointed out that when organizations invest heavily, will eventually form an efficient, integrated organizational processes and corresponding practices, to provide customers with the best service. The construction of university reflected in the improvement of university inherent capital, the rich structure capital has attractive to external resources. It also can promote university relationship capital increasing. It is likely, therefore, that a positive relationship exists between structure capital and relationship capital. This results in the following hypothesis:

H3: Structure capital has a positive impact on relationship capital.

Bontis's (2000) findings indicate that there is a clear causal relationship between most elements of intellectual capital and business performance. There are many domestic and foreign scholars having got the similar conclusion that there is a causal relationship between intellectual capital and corporate performance. Technology innovation performance refers to the university in the ever-changing to improve the management system, and fully mobilize the scientific and technological resources, organize innovative activities, which outputs a series of high-level scientific research. Enhancing technology innovation performance lies in the integration of resources and the allocation of university technology. Intellectual capital is presented as a new resource concept, indicating that in terms of the effectiveness and operability of integration and allocation of resources have been widely recognized. From the perspective of system theory, the various elements of university intellectual capital can be seen as an input. In the premise of a certain system input, innovation performance is the output through a variety of resources into universities, the system processor, access to technology achievements. So there must be some causal relationship between the university intellectual capital and innovation performance.

Human capital is the most active capital, with creativity and innovation, which is the core of intellectual capital and is the basis of value realization and value added. Bontis through questionnaires, studied the impact of intellectual capital of the two industry sectors in Malaysia-non-service industries and service industries on the corporate performance, the empirical results show that, regardless of the type of industry, human capital are important (Bontis, 1998). Zhu's (2005) empirical studies show that human capital is a key factor in deciding the enterprises performance. For colleges and universities, human capital is also an important source of innovation, the more abundant human capital, the more distinguished experts and professors universities have, the stronger the innovation capacity, therefore, the better the performance of university technology innovation. This leads to the following hypothesis:

H4: Human capital has a positive impact on the performance of university technology innovation.

Structure capital is the basic framework of organization, and it is also the processes of organization's operations to create value. Zhi & Tang's empirical results show that the structure capital-related variables have a significant effect on the rate of corporate total return, and the study also shows that based on the perspective of time series, there is a significant correlation between the structure capital and corporate performance (Zhi & Tang, 2005). Hsu and Wang (2012) point out that determining the structure capital of an organization is to determine the performance level of the organization, and they have proved structure capital has a positive impact on organization performance by the method of structure equation. The university structure capital includes infrastructure, regulations, campus culture, libraries and all university assets, etc. Structure capital is the foundation of university technology innovation. The richer the structure capital, the higher innovation platform, and technology performance innovation will also improve. This leads to the following hypothesis:

H5: Structure capital has a positive impact on the performance of university technology innovation.

Relationship capital emphasize the interest contact between organization and external stakeholders, behavior in any organization is rooted in the huge social network. Organization is one node in the network, and the level of ability to obtain external resources affected the development of organization. The ability to access external resources is constrained by external networks, and thus the relationship capital between organizations has a significant impact on the survival and development of the organization. Tseng and James (2005) studied manufacturing companies in Taiwan and found that the value of the company can arise through the good relations with all other participants in the external environment, such as customers, suppliers and other groups, and confirmed relationship capital has a positive impact on corporate performance. University as a social organization also has its social network, university relationship capital including networks, international cooperation, school honors, students, etc. The more relationship capital university has, the less time needed to collect the required information, the opportunity to exchange knowledge and the efficiency of information exchange will be higher accordingly. This leads to the following hypothesis:

H6: Relationship capital has a positive impact on the performance of university technology innovation.

2. THE SELECTION OF INDICATORS

University intellectual capital is divided into human capital, structure capital and relationship capital three factors, and most of the existing research build intellectual capital indicators from a business perspective, less from university perspective. Combining the three dimensions and Compilation of S&T statistics, this paper from the intellectual capital of human capital, structure capital and relationship capital three dimensions selected a total of 13 evaluation indicators. As following Table 1:

Table 1
The Indicators of University's Intellectual Capital

Dimension	Number	Indicators	Reference sources
Human capital	X_1	Graduate students involved in research	Jiang Yinhua (2012)
	X_2	Teaching and research staff	Wen-Min Lu (2012)
	X_3	Senior teaching and research staff	Victor Bucheli (2012)
	X_4	Research and development personnel	Yanjie Hu (2012)
	X_5	Senior research and development personnel	Yanjie Hu (2012)
Structure capital	X_6	Collection of books	Jiang Yinhua (2012)
	X_7	Master points	Jiang Yinhua (2012)
	X_8	National key disciplines	Yang Xiaoming (2009)
	X_9	State key laboratory	Victor Bucheli (2012)
	X_{10}	Science and technology funds	Wen Min Lu (2012)
Relationship capital	X_{11}	Project topics	I-Shuo Chen (2013)
	X_{12}	Issue expenses	Jiang Yinhua (2012)
	X_{13}	The number of international conferences	Yang Xiaoming (2009)

Technology innovation performance broadly includes innovation, innovation environment and innovation results, and technology innovation performance narrowly is based on input-output perspective, directly research the result of innovation (Bontis, 1998). This paper studies the relationship between university intellectual capital and technology innovation performance, thus regard intellectual capital as technology input, and technology innovation performance as research output. This paper extracted commonly used six indicators to reflect the university technology innovation performance. As following Table 2:

Table 2
The Indicators of University's Technology Innovation Performance

	Number	Indicators	Reference sources
Performance	Y1	Published monographs	Jiang Yinhua（2012）
	Y2	Identified achievement	Jiang Yinhua（2012）
	Y3	Research award	Yang Xiaoming（2009）
	Y4	The number of papers	I-Shuo Chen（2013）
	Y5	Technology transfer income	Hu Yanjie（2012）
	Y6	The number of patents granted	Yang Xiaoming（2009）

In this paper, 64 affiliated universities have chosen as objects for the study, the reasons are that: first of all, affiliated university's scientific research strength are stronger relatively, and that are the main force of technology innovation, while affiliated university in technology innovation has also been supported by national policies and multifaceted society. Secondly, in order to ensure the accuracy of the data, we choose 64 affiliated universities of which date have presented completely in Compilation of S&T statistics and removed the Central Academy of Drama and other art or non-comprehensive university away.

In terms of selecting data, 19 indicators data from 2009 to 2013 of 64 universities was selected as panel data for subsequent data analysis. Data from two major pathways, first, from the calendar year Compilation of S & T statistics, second, access to relevant data via the Internet its campus profile, the research team, discipline and other aspects of construction announced in the official website of the major colleges and universities.

3. METHODOLOGY

By the original data normality test, the data follow a normal distribution assumption is rejected, taking into account the small sample size, so the estimation method selected structural equation model based on partial least squares (PLS) algorithm. One feature of this technology is of no requirement for data distribution, and especially adapted to the small sample size analysis. This article select SmartPLS2.0 software, and use bootstrap method to extract 200 times, testing the stability of the corresponding estimation.

3.1 Measurement Model

The evaluation of measurement model consists mainly of the reliability of individual items, the reliability of combination, convergent validity and discriminant validity, the specific results of the analysis are shown in Table 3 and Table 4.

The reliability of individual items: Determine the reliability of individual items based primarily on the factor loadings, and accepted by most scholars loading coefficient standard is 0.7, as Table 3 shows, in addition to Y2, Y5 and Y6, the rest of the loading coefficient are greater than 0.7. In fact, Igbaria (1997) believe that when the loading coefficient is greater than 0.3, the result can be considered significant, greater than 0.4 means more important, 0.5 is very important. From this point of view, the loading coefficient of 0.346, 0.587 and 0.673 are acceptable.

The reliability of combination: The purpose of the reliability of combination is to ensure the internal consistency when measured variables are measuring the same latent variable. In this paper, the reliability of combination is greater than 0.8, and the indicators have a strong consistency according to Fornell's study (Fornell & Larcker, 1981).

Convergent reliability: convergent validity is to ensure that the measured variables can really measure the latent variable, Fornell and Larcher believe assessing convergent validity must analyze the average variance extracted (AVE), and AVE should be greater than 0.5 (Fornell & Larcker, 1981). Table 3 shows that all AVE of latent variables are greater than 0.5.

Table 3
Measurement Model

Factor	Loading coefficient	*T* values	CR	AVE
Human Capital			0.966	0.852
X1	0.717***	21.379		
X2	0.963***	184.174		
X3	0.978***	294.409		
X4	0.947***	126.293		
X5	0.982***	335.697		
Structure Capital			0.920	0.742
X6	0.832***	42.643		
X7	0.896***	69.399		
X8	0.900***	96.718		
X9	0.813***	48.246		
Relationship Capital			0.947	0.817
X10	0.950***	41.672		
X11	0.893***	62.803		
X12	0.924***	85.921		
X13	0.844***	36.554		
Performance			0.861	0.527
Y1	0.803***	27.969		
Y2	0.346***	5.234		
Y3	0.897***	64.413		
Y4	0.894***	66.455		
Y5	0.587***	8.926		
Y6	0.673***	13.870		

Note. ***P<0.01

Discriminant validity: Discriminant validity reflects ability to distinguish the different latent variables, and the most common detection method is the comparison between the square root of the AVE and correlation coefficient of the latent variables. It has good discriminant validity when the square root of AVE is greater than the correlation coefficient of the latent variables. Table 4 shows, the square root of AVE are greater than the correlation coefficient of the latent variables, indicating that with good discriminant validity.

Table 4
The Comparison Between the Square Root of AVE and the Correlation Coefficient

	HC	SC	RC	P
HC	0.923			
SC	0.772	0.861		
RC	0.846	0.719	0.904	
P	0.862	0.682	0.889	0.726

Note. Diagonal is the square root of AVE, the rest is the correlation coefficient of the latent variables

3.2 Structural Model

Predictive ability of the model can be judged by the R^2 and Redundancy. R^2 refers to the degree of the explained variance of endogenous latent variable, and the value between 0 and 1. We generally think that R^2 is greater than or equal to 0.5 is acceptable (Conhen, 1992). From Table 5 and Figure 1, the structural model's R^2 are greater than 0.5, and university technology innovation performance's R^2 is 0.8341, indicating that the theoretical model we build can explain the variability of its 83.41%, which means the predictive ability is quite satisfactory.

Table 5
Structural Model

Factor path	Path coefficient	*T* statistics	Conclusion
HC→SC	0.772****	33.4008	Support H1
HC→RC	0.721****	11.9024	Support H2
SC→RC	0.163***	2.8925	Support H3
HC→P	0.419****	5.1128	Support H4
SC→P	- 0.053	1.1500	Not support H5
RC→P	0.573****	7.6035	Support H6
Model fitting			
R^2	0.834		

Note. ***$P < 0.01$, ****$P < 0.001$

Human capital has a positive impact on the structure capital, improving the quality of human capital can make it easier to transfer individual knowledge into university knowledge, so as to enhance the university's structure capital. Human capital is also has a significant positive impact on the relationship capital, the higher the quality of human capital, the more frequent the ability to interact with the external environment for the university, access to more academic exchanges and funding. The results also show that the path coefficient from structure capital to relationship capital is 0.163, and it's significant on the level of 1%, so the structure capital have a significant positive impact on the relationship capital.

University intellectual capital is the knowledge base of technology innovation, and there is a positive impact on technology innovation. Human capital and relationship capital has a significant impact on technology innovation performance, the more abundant human capital and relationship capital, the more distinguished experts and professors universities have, the stronger the innovation capacity, the less time needed to collect the required information, the opportunity to exchange knowledge and the efficiency of information exchange will be higher accordingly.

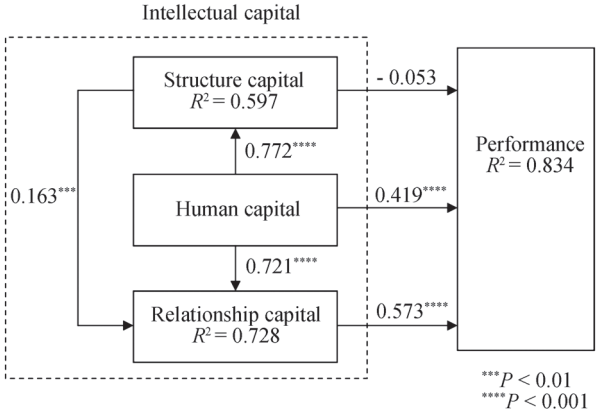

Figure 1
Research Framework and Analyze Results

3.3 Mediating Effect Test

Structure capital's direct influence on technology innovation performance has not been verified, in order to test the structure capital's overall effect on technology innovation performance, this paper examines the indirect effect through testing mediating effect. Sobel test is a common method of mediating effect test, but there is a drawback that it requires statistics corresponding indirect effect following a normal distribution (Hayes, 2009), so this study used Mackinnon (2008) method to test. As Table 6 shows, relationship capital as mediating variable, the Mackinnon mediating effect test of structure capital to technology innovation performance at 95% confidence interval does not contain zero, the values were 0.0245 and 0.1882. According to the above results, the structure capital of this research has full mediation effect on technology innovation by relationship capital as mediator. Table 6 also shows that human capital dose not only have a direct effect on technology innovation performance, but also has a indirect effect by relationship capital as mediator, but human capital through structure capital effect technology innovation performance has no corresponding mediating effect.

Table 6
Mackinnon's Mediating Effect Test

	MacKinnon PRODCLIN2	
	95% CI	
Indirect effects	Lower	Upper
HC→SC→P	- 0.1060	0.0300
HC→SC→P	0.2610	0.5970
HC→SC→P	0.0245	0.1882

CONCLUSIONS AND DISCUSSION

Although the research on university innovation performance has accumulated a lot, but from the quantitative point of view, mostly using data envelopment analysis and stochastic frontier analysis techniques, the researches combining intellectual capital and university performance are less relatively. This article uses PLS, from a quantitative perspective to discuss the relationship between the three main components of university intellectual capital, and on this basis, analyzes the impact of intellectual capital on the university's innovation performance.

Findings show that human capital has a significant role in promoting structure capital and relationship capital, while the structure capital also showed a significant role in promoting relationship capital, improving visibility for the promotion of human capital. It is critical to enhance the intellectual capital. It shows that improving human capital is critical for the promotion of intellectual capital. The study also found that human capital and relationship capital directly and positively affect technology innovation performance significantly, while the structure capital also has full mediation effect on technology innovation performance. Overall, therefore, university intellectual capital affect innovation performance significantly.

Based on the above findings and analysis, we can get the following inspiration: First of all, the cultivation and reserves of innovative talents is a key factor to improve the performance of university technology innovation. Universities should adopt the way combining self-cultivation and introduction to build innovative team which closer to social and market. Secondly, we must pay attention to the coordinated development of human capital and relationship capital, focus on information exchange and cross-disciplinary will be more conducive to innovation. Universities need to not only focus on inherent human capital, but also introduce external manpower and information widely, and combine the local capital and external relations capital at the greatest degree. Third, we should optimize the structure capital, which is an important material foundation of university technology innovation, universities through a series of complex exploration, research and innovation, and to ultimately enhance structure capital. The growth of structure capital can enhance the relationship capital, last form a virtuous cycle.

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