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Alternative Causal Relationship among Components of Intellectual Capital in Korean Public R&D Organizations

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ABSTRACT

This paper developed measurement indices for intellectual capital of public R&D organizations and investigated causal relationships among the components. We developed 10 measurement factors and 37 indicators and confirmed the reliability of these measurements. We offered an alternative to the existing model for searching causal relationships. From our survey research, using the structural equation model, we found a new relationship. In contrast to the existing model, we found a cycling relationship among three variables: human capital causes structural capital, structural capital causes relational capital, and relational capital causes human capital.

Keywords: intellectual capital, measurement index, causal relationship, public R&D organizations, structural equation model.

Ⅰ. Introduction

According to resource-based theory, sustainable competitive advantage comes from resources that are very difficult for others to imitate and to replace. The resources are usually implicit rather than explicit. “They emphasize the strategic importance for managers to identify 'a set of complementary and specialized resources and capabilities, which are durable, not easily traded, and difficult to imitate' to enable the company to earn an economic profit.” “Firms without valuable, rare, or imperfectly imitable cultures cannot expect their cultures to be the source of sustained competitive advantages.” (Barney, 1991; Amit & Shoemaker, 1993). Those features are financial capital, physical capital, human capital, and organization capital, which are accumulated inside the firm and can be called intellectual capital (Barney, 2002). Intellectual capital is classified into three sub-categories; human capital, structural capital, and relational capital (Stewart, 1997; Sveiby, 1997; Edvinsson, 1997).

This paper studies for developing measurement indices and investigating causal relationships among the components of intellectual capital in public R&D organizations. Intellectual capital in R&D organizations is not the same as those in firms generally. Thus, we need to consider the characterization of R&D organization when we research the relationships. Regarding human

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capital, highly educated scientists who have know-how in their field are core assets in R&D organizations. Their experience, knowledge, skills, academic degrees, variety of their background, and the depth of their knowledge are very important (ETRI, 2005; Mettänen, 2005; Suzuki, 2006; Jyoti, 2008). Structural capital includes brand, strategy, culture, reputation, and images. Market-oriented R&D activity might encourage innovative ability and organization culture is also critical to their success (Pike, 2005; Mettänen, 2005; ETRI, 2005). Relational capital includes the cooperation of external experts and the research organization. Close relations with other research institutions and universities can improve the organizations' ability, and this can provide positive performance effects (ETRI, 2005; Chu, 2006; Torres, 2006; Jyoti, 2008).

The output of R&D organizations is usually invisible, including intangible technologies and intellectual capital. Thus, we can get some important implications from the research of intellectual capital for improving the performance of R&D organizations.

Ⅱ. Research model and hypotheses

1. Design for the research model

Existing literature considers that human capital causes structural capital and relational capital (Bontis, 1998, 2000, 2002, 2009; Chen, 2004; YunJi Moon, 2006). This means that an individual member of the organization creates value, which, in turn, affects the structural capital and relational capital of the organization. The literature also considered that structural capital affects relational capital.

Bontis (1998) found that the paths 'human capital → structural capital → customer capital' and, at the same time, 'human capital → customer capital' were statistically significant. Similarly, Chen (2004) found that 'human capital → structural capital → customer capital,' and Moon (2006) found 'human capital → relational capital → structural capital' too. These results are similar to the results of strategy maps of the balanced score card (Kaplan & Norton, 2004). They offered a path, 'Learning & Growth (Human Capital) → Internal Process (Structural Capital) → Customer (Relational Capital).'

However, these findings were from firms generally, rather than R&D organizations. We applied the models to the R&D organizations initially and presented our findings as 'basic model' in this paper. In the 'basic model' we have two paths; 'human capital → structural capital → relational capital' and 'human capital → relational capital' (Fig. 1a).

Nonetheless, we might consider a slightly different causal relationship in R&D organizations. We might consider a hypothesis that the competency of individual researchers can be improved more through networking and cooperation with external experts (i.e., relational capital of an organization), than through human capital. From recent research, we found more cases that individual researchers are improving their competency by interdisciplinary study with experts of various fields. From these activities relational capital is increased and research quality can be improved. It is not easy to explain why relational capital should affect human capital, if we use only the basic model.

Thus, an alternative model is needed to address this problem, which might include the path 'relational capital → human capital.' Unfortunately, we could not identify a significant amount of literature covering this problem. An interesting paper by Torres (2006), in which universities were used, found the path 'human capital → structural capital → relational capital → human capital' to be statistically significant.

This research presented uses Torres (2006) as a base and gives more contribution by using experiences in Korean public R&D organizations. We considered a cycling causal relationship among three variables; 'human capital → structural capital → relational capital → human capital' and we offered it as 'alternative model' (Fig. 1b).

In this research, we tried to identify the difference of aspect clearly by way of comparison with using two different models to be suggested. The one is 'basic model' which is come from existing research findings, the other is 'alternate model' which is come from creative ideas and experience from R&D field.

Using these two models, we proposed the following hypotheses:

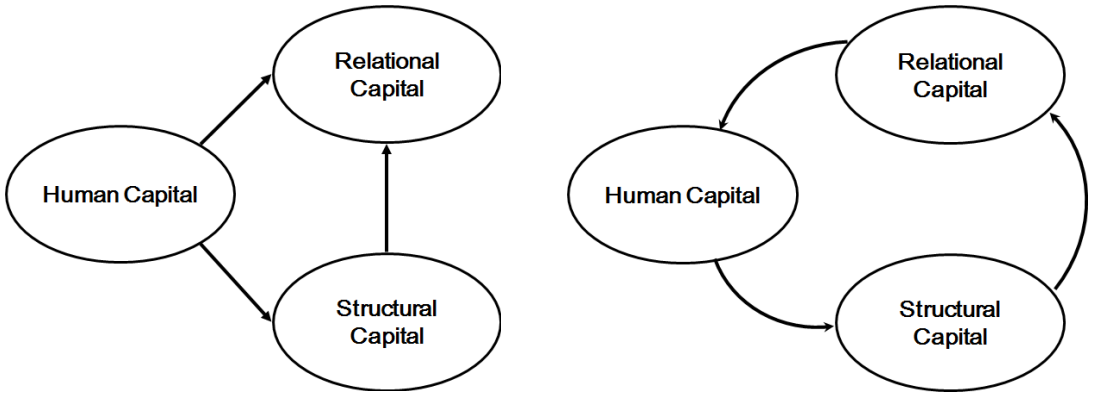
Hypothesis 1: Human capital affects structural capital in a positive direction.

Hypothesis 2: Structural capital affects relational capital in a positive direction.

Hypothesis 3:

A. Basic model: Human capital affects relational capital in a positive direction.

B. Alternative model: Relational capital affects human capital in a positive direction.



(a) basic model (b) alternative model

[Figure 1] Causal relationship among the components of intellectual capital

Ⅲ. Research methodology

1. Process of measurement indices development for intellectual capital

We developed measurement indices for intellectual capital in public R&D organizations using three stages of research.

First, we reviewed the literature relating to the theoretical background of intellectual capital in the public R&D organizations, covering the components of measurement index. Göran Roos (2005) discussed five resources for the intellectual capital: human resources, organizational resources, relational resources, physical resources, and monetary resources. Suzuki (2006) included researcher's community, R&D funds, R&D procedures, R&D time required, and researcher's training into a measurement index. Chu (2006) considered a measurement index from the researcher's viewpoint.

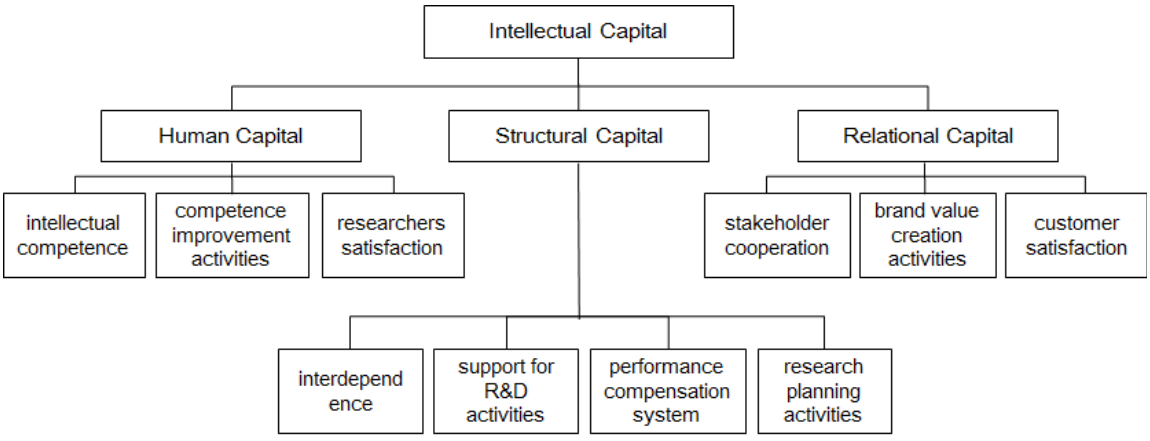
ETRI (Electronics and Telecommunications Research Institute in Korea) included R&D network and R&D value creation as resources.

Second, we developed the measurement factors and indicators for intellectual capital in public R&D organizations. We developed 17 measurement factors and 88 measurement indicators of intellectual capital as candidates. We proposed indicators as many as possible because we wanted to offer them to the experts for screening in step 3.

Third, we discussed these candidates with experts in the public R&D organizations (e.g., R&D management, statistics, R&D performance management, human resource management) and used their comments and suggestions to refine the indices. We also pre-tested the indices with employees of public R&D organizations for reliability. From these investigations we finally obtained 10 measurement variables for intellectual capital and 37 indicators. These stages are summarized in Table 1. The measurement indices developed in this paper are shown in Figure 2.

[Table 1] Three stages for developing the measurement indices for intellectual capital

Step	Activities	Activity results
1	Survey of previous studies on intellectual capital in public R&D organizations	. Survey on measurement indices of intellectual capital for both of profit and R&D organization . Indices development along with mission for R&D organization
2	Measurement indicators development for public R&D organizations	. Draft indicators developed: 17 factors, 88 Indicators
3	Expert review of developed draft indicators	. Expert validation review on draft indicators . Pre-test for validation by R&D organization experts . Development of the final measures for intellectual capital in public R&D organizations: 10 factors, 37 indicators



[Figure 2] Measurement indices of intellectual capital in public R&D organizations

2. Measurement indices for intellectual capital in R&D organizations

Development of measurement indices for R&D organizations should be considered R&D organization's characteristics. Human capital is related to researchers' experience, knowledge, competence, skills and is linked to university degree, academic diversities, knowledge depth (ETRI, 2005; Mettänen, 2005; Suzuki, 2006; Jyoti, 2008).

Structural capital is related to brand, strategy, culture, reputation and image of the R&D organization. Market oriented strategy promotes innovation capabilities. Organizational culture makes key success factors of creating performance (Pike, 2005; Mettänen, 2005; ETRI, 2005).

Relational capital is linked to cooperation with external expert and internal researchers. Organizational competence is raised by relationship with external R&D institute and universities. R&D performance is enhanced by interdisciplinary studies with other institute (ETRI, 2005; Chu, 2006; Torres, 2006; Jyoti, 2008). Factor of 'cooperation with stakeholder' is measured with respect to wide range of stakeholders and customers cooperation. These stakeholders and customers mean not only the R&D fund providers but also facilitators in the process of performing R&D activities, so 'cooperation with stakeholder' is should be important index to measure the relational capital for R&D organization.

Table 2, Table 3 and Table 4 show the conceptual definition and indicators developed for human capital, structural capital and relational capital.

[Table 2] Conceptual definition and Indicators' name for human capital

Factor	Conceptual Definition	Indicator
1. Intellectual Competence	Competence of researchers for R&D activities	1) Educational Level
		2) level of professional competence
		3) level of know-how
2. Competence improvement activities	Quality of Education Program for Researchers for competence enhancing	4) education investment
		5) training time
		6) competence improvement program
		7) career development training program
3. Researcher's satisfaction	Satisfaction Level and attitude as each member of researchers	8) creativity
		9) openness
		10) workplace satisfaction
		11) worthwhileness

[Table 3] Conceptual definition and indicators' name for structural capital

Factor	Conceptual Definition	Indicator
4. Interdependence	Communication and mutual cooperation level in the organization	12) peer-to-peer communication
		13) communication up and down the organization
		14) absorbing outside ideas and open attitude
		15) communication between research and support departments
5. Support for R&D activities	Supporting system level for R&D activities in the process of creating a performance	16) operating levels of R&D management
		17) research materials procurement system
		18) performance management system
		19) computer support system
		20) efficiency of R&D processing procedures
6. Performance compensation system	Performance evaluation and compensation system level for researchers	21) fairness of performance evaluation procedures
		22) individual performance compensation system
		23) rationality of promotion system
		24) rationality of excellent staff award
7. Research planning activities	R&D planning system level for research activities including organization strategy	25) establishment and utilization of mid-long term development plan
		26) R&D project planning activities
		27) generation and utilization of excellent idea

[Table 4] Conceptual definition and indicators' name for relational capital

Factor	Conceptual Definition	Indicator
8. Cooperation with stakeholders	Mutual cooperation level with customers in the value creation process	28) domestic stakeholder cooperation
		29) international stakeholder cooperation
		30) perform collaborative research with external partners
9. Brand value creation activities	Value creation activities level for improving organization brand	31) publicity[information] activities
		32) investment promotion activities
		33) Society Contribution Service
		34) customer relationship management activities
10. Customer's satisfaction	Satisfaction level to the organization of customers	35) customer satisfaction on research results
		36) re-request of R&D project by customers
		37) growth of research partnerships

3. Questionnaire

We surveyed Korean public R&D organizations in the field of natural science; 26 research institutions are operated by the Korean government (government-supported research institutes (GRIs)), covering almost all science fields, including 'standards, mechanical engineering, chemistry, biotechnology, atomic energy, electronic and telecommunication.' They have 13,000 researchers and an annual budget of $30 B (2008 data).

For the purpose of this research, we applied to the unit of R&D organization for the survey. The questionnaires were delivered to the R&D project managers and the heads of independent research departments. The survey was conducted during in April 2009 (April 11~18). The questionnaires were provided to 635 people, of which 264 responses were received.

4. Statistical analysis

SPSS version 14.0 and AMOS version 7.0 were used.

Ⅳ. Results

1. Validity of the model

1.1 Reliability

Due to the use of a large number of indicators to measure one concept, testing reliability was necessary. As shown in the Table 5, values of Cronbach's alpha were above 0.7 (0.770-0.929), showing internal consistency.

[Table 5] Validity tests of the indicators for intellectual capital

Dimension	Factors	Indicators	Average	Standard deviation	Cronbach's alpha
Human capital	Intellectual competence	3	5.96	0.70	0.770
Human capital	Competence improvement activities	4	4.19	1.05	0.888
Human capital	Researcher's satisfaction	4	5.32	0.81	0.788
Structural capital	Interdependence	4	4.81	0.91	0.847
Structural capital	Support for R&D activities	5	4.73	0.94	0.875
Structural capital	Performance compensation system	4	4.58	1.06	0.929
Structural capital	Research planning activities	3	4.88	0.98	0.866
Relational capital	Cooperation with stakeholders	3	4.97	0.89	0.841
Relational capital	Brand value creation activities	4	4.63	0.94	0.838
Relational capital	Customer's satisfaction	3	5.02	0.86	0.834

1.2 Confirmatory factor analysis

We used principal component analysis with Varimax rotation and the results are shown in Table 6. From the discriminant validity analysis of the indicators for human capital, we obtained three factors: competence improvement activities, researcher's satisfaction, and intellectual competence (Table 6).

From the validity analysis for structural capital, four factors were obtained: Support for R&D activities, Performance compensation system, Interdependence, and Research planning activities (Table 7).

For relational capital, there were three factors: Brand value creation activities, Cooperation with stakeholders, and Customer's satisfaction (Table 8).

We can confirm that 10 measurement factors designed in the paper are valid from the results.

[Table 6] Rotated factor matrix for human capital variable

	Factors			Communality
	1	2	3	
Intellectual competence 1	-0.012	0.177	0.831	0.722
Intellectual competence 2	0.122	0.055	0.896	0.820
Intellectual competence 3	0.062	0.307	0.693	0.578
Competence improvement activities 1	0.827	0.093	0.087	0.700
Competence improvement activities 2	0.882	0.069	0.033	0.783
Competence improvement activities 3	0.880	0.167	0.029	0.804
Competence improvement activities 4	0.831	0.135	0.061	0.713
Researcher's satisfaction 1	0.057	0.762	0.117	0.597
Researcher's satisfaction 2	0.045	0.797	0.060	0.640
Researcher's satisfaction 3	0.206	0.724	0.207	0.609
Researcher's satisfaction 4	0.175	0.737	0.226	0.624
Eigen value	3.978	2.257	1.355	
% of variance	36.167	20.522	12.319	
% of cumulative variance	36.167	56.690	69.009	

[Table 7] Rotated factor matrix for structural capital variable

	Factors				Communality
	1	2	3	4	
Interdependence 1	0.152	0.216	0.821	0.177	0.776
Interdependence 2	0.119	0.264	0.821	0.134	0.776
Interdependence 3	0.140	0.140	0.713	0.373	0.686
Interdependence 4	0.447	0.280	0.614	0.070	0.659
Support for R&D activities 1	0.765	0.278	0.196	0.187	0.735
Support for R&D activities 2	0.772	0.277	0.202	0.081	0.721
Support for R&D activities 3	0.644	0.402	0.152	0.306	0.693
Support for R&D activities 4	0.839	0.083	0.098	0.172	0.750
Support for R&D activities 5	0.594	0.249	0.150	0.360	0.567
Performance compensation system 1	0.300	0.780	0.271	0.232	0.826
Performance compensation system 2	0.257	0.825	0.258	0.213	0.859
Performance compensation system 3	0.271	0.761	0.340	0.237	0.824
Performance compensation system 4	0.270	0.761	0.175	0.303	0.774
Research planning activities 1	0.220	0.436	0.176	0.658	0.703
Research planning activities 2	0.248	0.216	0.238	0.815	0.829
Research planning activities 3	0.238	0.247	0.244	0.810	0.833
Eigen value	8.447	1.457	1.119	0.987	
% of variance	52.795	9.108	6.993	6.169	
% of cumulative variance	52.795	61.903	68.896	75.066	

Notes: Factor 1 (Support for R&D activities), Factor 2 (Performance compensation system), Factor 3 (Interdependence), Factor 4 (Research planning activities). Factor 4 is included even though the Eigen Value is below 1 because Eigen value is approach to 1 and Factor 4 (Research planning activities) is important factor in R&D organization.

[Table 8] Rotated factor matrix for relational capital

	Factors			Communality
	1	2	3	
Cooperation with stakeholders 1	0.278	0.747	0.257	0.701
Cooperation with stakeholders 2	0.223	0.852	0.145	0.796
Cooperation with stakeholders 3	0.176	0.806	0.333	0.792
Brand value creation activities 1	0.700	0.287	0.214	0.618
Brand value creation activities 2	0.842	0.231	-0.022	0.763
Brand value creation activities 3	0.815	0.087	0.260	0.740
Brand value creation activities 4	0.722	0.219	0.297	0.658
Customer's satisfaction 1	0.237	0.331	0.779	0.772
Customer's satisfaction 2	0.073	0.176	0.889	0.826
Customer's satisfaction 3	0.343	0.236	0.721	0.693
Eigen value	5.039	1.328	0.993	
% of variance	50.390	13.279	9.930	
% of cumulative variance	50.390	63.670	73.600	

2. Validity of causal relationship among the components of intellectual capital

2.1 Tests for the basic model

Table 9 showed the results of the analysis of goodness-of-fit in the basic model. It generally leaded to the conclusion that basic model met the requirements even though 'RMSEA' index does not meet a little to the reference value.

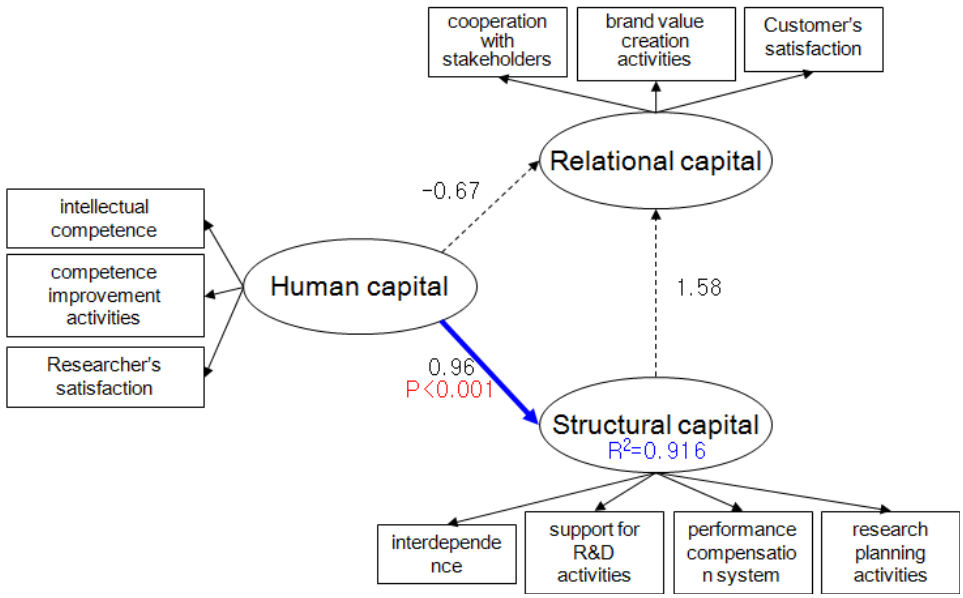
Table 10 showed the results of the analysis of causal relationships in the basic model using a structural equation model method.

[Table 9] Goodness-of-fit of basic model

Model	χ2	DF	GFI	AGFI	CFI	RMSEA
basic model	73.8	24	0.946	0.876	0.960	0.089

[Table 10] Path analysis of basic model

Hypotheses	Path	Standardized regression weight	Standard error	C.R. (critical ratio)	P	Whether to adopt
1	human capital → structural capital	0.957	0.161	8.048	0.000	Accepted
2	structural capital → relational capital	1.578	1.019	1.409	0.159	Rejected
3	human capital → relational capital	-0.674	1.394	-0.595	0.552	Rejected



[Figure 3] Tests of causal relationship: basic model

From the path analysis in Table 10, only Hypothesis 1 (human capital → structural capital) was shown to be significant. Hypothesis 2 (structural capital → relational capital) and Hypothesis 3 (human capital → relational capital) did not seem to be significant. These results were different from the existing literature, where research investigated firms generally (human capital → structural capital, human capital → relational capital, structural capital → relational capital) (Bontis 1998, 2000, 2002, 2009; Chen, 2004; Moon, 2006). This difference seemed to be because of the idiosyncratic characteristics of R&D organizations.

2.2 Tests for the alternative model

Table 11 showed the results of the analysis of goodness-of-fit in the basic model. The alternative model performed as well as the basic model.

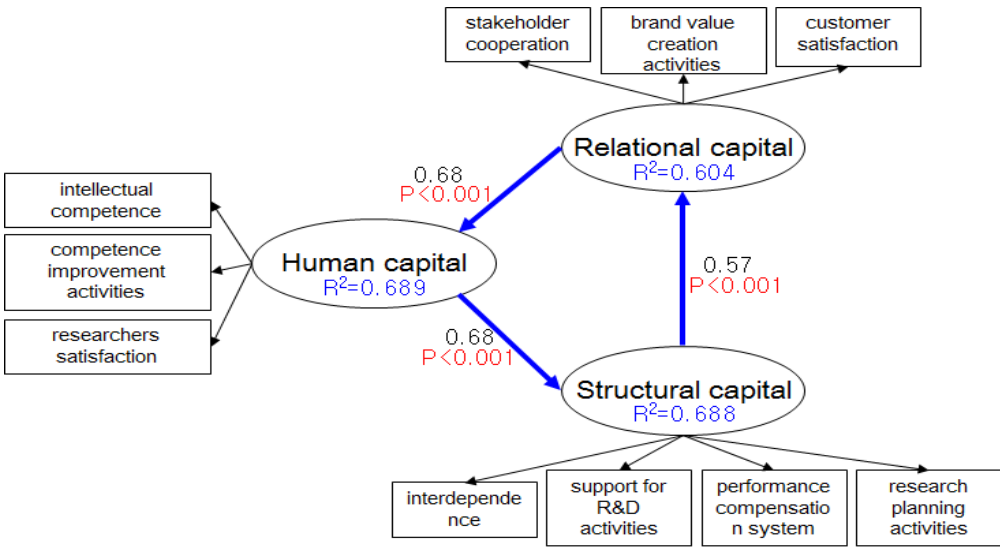
In Table 12, we showed the results from the path analysis for the alternative model.

[Table 11] Goodness-of-fit of alternative model

Model	χ2	DF	GFI	AGFI	CFI	RMSEA
Alternative model	70.063	23	0.949	0.878	0.962	0.088

[Table 12] Path analysis results for the alternative model

Hypotheses	Path	Standardized regression weight	Standard error	C.R. (critical ratio)	P	Hypotheses result
1	human capital →structural capital	0.682	0.227	4.658	0.000	Accepted
2	structural capital → relational capital	0.566	0.123	3.665	0.000	Accepted
3	human capital → relational capital	0.683	0.108	5.139	0.000	Accepted



[Figure 4] Causal relationship of the alternative model

The result from the path analysis showed statistical significance for the following hypotheses: Hypothesis 1 (human capital → structural capital), Hypothesis 2 (structural capital → relational capital), and Hypothesis 3 (relational capital → human capital). These results were quite different from the previous research and were consistent with Torres (2006).

2.3 Comparison of the two models

Comparing the goodness-of-fit indices of the two models provided in Tables 9 and 11, there was no evidence that the alternative model was superior to the basic model; the numbers were very similar. However, we presented convincing evidence that the alternative model performed much better than the basic model in terms of significance relating to path coefficients, as presented in Tables 10 and 12.

In the basic model, only Hypothesis 1 (human capital → structural capital) was significant. In the alternative model, the cycling causal relationship among three capitals was significant ($p < 0.001$), which is 'human capital → structural capital → relational capital → human capital.' This could mean that the path for causal relationship 'relational capital → human capital' might be more valid than the path 'human capital → relational capital.' In R&D organizations, it would be more reasonable to think that the causal relationship seemed to be cyclic among the components of intellectual capital.

Ⅴ. Conclusions

This paper developed measurement indices for intellectual capital of public R&D organizations and investigated causal relationships among the components. We developed 10 measurement factors and 37 indicators and checked reliability. We offered an alternative to the existing model for searching for causal relationships. From our research of representative public research institutions in Korea, using the structural equation model, we found a new relationship.

In contrast to the existing model, where the causal relationships of 'human capital → structural capital, human capital → relational capital, structural capital → relational capital' were obtained, we found a cyclic relationship among the three variables: human capital causes structural capital, structural capital causes relational capital, and relational capital causes human capital (human capital → structural capital → relational capital → human capital).

We got a new result in this study that the relationship between relational capital and human capital (relational capital → human capital) was significant. It may be possible to say that the interaction of shareholders and customers in process of R&D activity is important to improve their human capital. It may be available to emphasize the relational activities for raising human capital in real R&D field.

This study had the limitation of that we did not consider the characteristics of each R&D organization in the process of developing indices. And it would be good to study of the intellectual capital including tangible asset, for example, R&D fund amount, research facilities, etc.

As a conclusion, we need to keep in mind that R&D organizations are different from private firms generally and they have their own characteristics. This seems to be one of the reasons we need to develop a new model to analyze relationships among the variables in the study. We hope that the results presented here can be used to build intellectual capital management strategies in other organizations including non-profit organizations or other public organizations.

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저 자 소 개

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서울대학교 경영대학을 졸업하고 미국 알라바마 대학에서 경영학박사를 취득하였다. 1985년 이후 충남대학교 경영학부 교수로 재직하고 있으며 재무관리, 벤처캐피탈, 기술가치 평가가 주요 관심분야이다.

전 병 훈 (Byoung Hoon Jeon)

충남대학교에서 경영학(기술경영) 전공으로 박사학위를 취득하고 현재 한국표준과학연구원에 재직 중이다. 연구개발 조직에서의 지적자본 측정 및 인과관계, 성과관리, 국가표준체계 전략수립이 주요 관심분야이다.

김 능 진 (Nung Jin Kim)

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