An empirical study of dynamic capabilities measurement on R&D department

Liang-Yang Lin*

Department of Business Administration,
Fu Jen Catholic University,
510, Chung Cheng Road, Hsinchuang,
Taipei County 24205,
Taiwan, ROC
E-mail: aug668@gmail.com
*Corresponding author

Se-Hwa Wu

Graduate Institute of Technology and Innovation Management,
National Chengchi University,
64, Chih-Nan Road, Sec. 2,
Taipei 116,
Taiwan, ROC
E-mail: sehwa@nccu.edu.tw

Binshan Lin

College of Business Administration,
Louisiana State University,
Shreveport,
LA 71115, USA
E-mail: binshan.lin@lsus.edu

Abstract: Dynamic capabilities can appropriately explain why the enterprises can respond to the rapidly changing environment. This paper is an empirical study exploring the effects of R&D department's dynamic capabilities on innovative performance in Taiwan and South Korea. We argue that R&D department's dynamic capabilities will have positive effects on innovative performance. Hypotheses were tested using regression analysis. Results showed that this research has a good reliability and validity. Results also showed that combinative capabilities, absorptive capacity, and flexibility have positive effects on innovative performance. However, there might have other moderator existed to affect the relationship between combinative capabilities and innovative performance.

Keywords: absorptive capacity; combinative capabilities; dynamic capabilities; flexibility; innovative performance; innovation; knowledge integration; learning; R&D.

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Biographical notes: Dr. Liang-Yang Lin obtained his PhD in Graduate Institute of Technology and Innovation Management in 2007 at the National Chengchi University, Taiwan. Currently he is an Assistant Professor of the Fu Jen Catholic University. Before entering the PhD programme, he was a Researcher of Industrial Technology Research Institute for three years. Now, he does researches on the subjects of R&D management and innovative management.

Dr. Se-Hua Wu obtained his PhD in business administration in 1984 at the National Chengchi University, Taiwan. He is a senior research professor within the Graduate Institute of Technology and Innovation Management and is currently the president of the National Chengchi University. As a talented researcher, he also serves as a consultant for Taiwan government.

Dr. Binshan Lin is the BellSouth Corporation Professor at the College of Business Administration, Louisiana State University in Shreveport. He received his PhD from the Louisiana State University in 1988. He is a seven-time recipient of the Outstanding Faculty Award at LSUS. He receives the Computer Educator of the Year by the International Association for Computer Information Systems (IACIS) in 2005. He has published over 160 articles in refereed journals, and currently serves as an Editor-in-Chief of nine academic journals.

1 Introduction

In the field of strategic management, the Resource-Based View (RBV) is an influential theoretical framework. Some scholars think that RBV can explain why the business firms can have sustainable competitive advantages (Teece, 1984; Wernerfelt, 1984). While the businesses have valuable, rare, inimitable, and non-substitutable resources, they can perform even better than their competitors through implementing new valuable and creative strategies, and in the mean time, the competitor cannot duplicate their strategies with ease (Wernerfelt, 1984; Eisenhardt and Martin, 2000; Ahsan, Kumara and Herath, 2007; Hsu, Lawson and Lin, 2007; Wickramasinghe, 2007).

In addition, in order to explain why some businesses can still keep their competitive advantages in the rapidly changing and unexpectable markets, some scholars expand RBV to dynamic markets and propose the concept of dynamic capabilities (Teece, Pisano and Shuen, 1997; Eisenhardt and Martin, 2000; Zollo and Winter, 2002). The fundamental reason is RBV cannot appropriately clarify how and why some businesses have competitive advantages under rapidly changing and unanticipated environments (Eisenhardt and Martin, 2000). The scholars who promote the concept of dynamic capabilities consider that while the firm has the ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments, it achieves the competitive advantages from learning to form distinct processes. These processes are shaped by the firm's various unique positions in specific assets and by the evolution paths that it has adopted (Teece, Pisano and Shuen, 1997). The proposition of the dynamic capabilities puts forward a very favourable explanation and clarification for the fact that the firms still can keep their competitive advantages in the rapidly changing and unexpectable markets. This makes up the deficiency of RBV.

Businesses have to continually pay a close attention to the change of external environments while operating. Some of the variations are crises coming all of a sudden, and have an urgency to be solved immediately (Lubitz and Wickramasinghe, 2006; Wei et al., 2006). Some of the variations are emerging opportunities that can often help the firms expand their businesses or consolidate their leadership in the industries, if they can seize them with righteousness. In today's knowledge based economy, sustainable strategic advantages are gained more from an organisation's knowledge assets than from the more traditional types of economic resources (Teswanich, Anutariya and Wiuwongse, 2006; Wickramasighhe, 2006). Although most of the scholars agree that strategic resources are the critical key in business operation, the firm cannot transform and utilise them effectively to generate innovations without appropriate capabilities and competences, even though it has rare, unique, and non-substitutable resources. On the contrary, a firm with appropriate capabilities and competences can make a good use of the external and internal resources to generate innovations so that it can grasp the emerging opportunity or solve the crisis, even though it does not have enough resources itself. In other words, in order to deal with the opportunities and threats in the external environments, firms must display their dynamic capabilities to reconfigure and integrate internal and external resources, knowledge, and competences so as to develop new technologies or products.

Although there were some scholars proposed their viewpoints of dynamic capabilities (Teece, Pisano and Shuen, 1997; Eisenhardt and Martin, 2000; Zollo and Winter, 2002; Adner and Helfat, 2003; Blyler and Coff, 2003; Sher and Lee, 2004), this field still awaits more relevant scholars to contribute from the empirical studies. This is the purpose why we devoted ourselves to the developing of measurement tool of dynamic capabilities to explore its generalisation in different countries. Based on this, there are two research questions of this study. First, can this measurement tool on dynamic capabilities (three dimensions with eight factors) with reliability and validity apply to two Asian countries, Taiwan and South Korea? Secondly, what is the relationship between dynamic capabilities of business R&D department and innovative performance?

2 Literature review

2.1 Dynamic capabilities

Although many scholars propose good perspectives on RBV, it has been called conceptually blurred and lack of empirical grounding. In addition, it cannot appropriately explain why some businesses can have competitive advantages under rapidly changing and unexpectable environments (Williamson, 1999). Therefore, some scholars expand RBV to dynamic markets and propose the perspectives of dynamic capabilities.

Teece, Pisano and Shuen (1997) propose that dynamic capabilities are the source of competitive advantage. They consider that the competitive advantage of firms is seen as resting on distinctive processes (ways of coordinating and combining), shaped by the firm's specific asset positions and the evolution paths it has adopted or inherited. Eisenhardt and Martin (2000) view dynamic capabilities as firm's processes that use resources to match and even create market change. Thus, they think that dynamic

capabilities are the organisational and strategic routines by which the firms achieve new resource configurations as markets emerge, collide, split, evolve, and die. In opposition to the argument of Teece, Pisano and Shuen (1997), Zollo and Winter (2002) emphasise that businesses do still integrate, build, and reconfigure their competences even in the low rates of changing environments. They define dynamic capability as a learned and stable pattern of collective activity through which the business systematically generates and modifies its operating routines to improve effectiveness. Furthermore, in order to underpin the finding of heterogeneity in managerial decisions and firm performance in face of changing external conditions, Adner and Helfat (2003) introduce the concept of dynamic managerial capabilities. They depict that dynamic managerial capabilities are the capabilities with which the managers build, integrate, and reconfigure organisational resources and competences, and they also reflect three underlying factors; managerial human capital, managerial social capital, and managerial cognition, to influence the strategic and operational decisions of managers. Different from others researches, Blyler and Coff (2003) focus their study on social capital and propose that social capital is a necessary, though not sufficient, condition for a dynamic capability. They consider that the ability to manage resource flows to create valuable combinations may be a meta-capability, and very hard to replicate. In addition, Helfat and Peteraf (2003) propose the concept of dynamic resource-based theory to the evolution of organisational capabilities. They argue that an organisational capability refers to the ability of an organisation to perform a coordinated set of tasks, utilising organisational resources, for the purpose of achieving a particular end result. They classify capabilities as either 'operational' or 'dynamic', and explain the differences between them. The research of Sher and Lee (2004) focused on the question: Does knowledge management contribute to the enhancement of dynamic capabilities and thus to the enhancement of business excellence and competitive advantage? They thought that the dynamic capabilities refer to an organisation's ways of responding in a rapidly changing environment. Their empirical findings suggested that the management of both endogenous and exogenous knowledge through information technology applications significantly enhances dynamic capabilities.

Through the paper reviews, this research finds that the dynamic capabilities' definitions of various scholars are somewhat different. Therefore, this research goes on further exploration of the concept of dynamic capability to extract its dimensions.

2.2 Dimensions of dynamic capabilities

According to the primary researches related to dynamic capabilities, this study abstracts and rearranges their major arguments so as to get the results summarised in Table 1. Taking the research of Teece, Pisano and Shuen (1997) as an example, our study puts the processes of coordination/integration, and reconfiguration and transformation into the first construct, named 'combinative capabilities'. Next, we put the learning processes into the second construct, named 'absorptive capacity'. This construct also includes the concept of repetition and experimentation of learning, and path dependence related to learning. Finally, we put the concept of dynamic, competitive flexibility, timely responsiveness, rapid and flexible product innovation, and high-flex into the third construct, named 'flexibility'.

Table 1 Review of dynamic capabilities

	Combinative capabilities	*Absorptive capacity*	*Flexibility*
Teece, Pisano and Shuen (1997)	The ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments Coordinate and integrate Reconfigure and transform	Leaning processes Frequent practices and experimentation The ability to scan and sense the environment Path dependency concerning leaning	Dynamic Competitive flexibility Timely responsiveness Rapid and flexible product innovation High-flex
Eisenhardt and Martin (2000)	The processes to gain, integrate, and reconfigure resources	Learning mechanisms Repeat experiments Effective learning Real-time information Path dependency concerning leaning	Simple, limited, and highly experiential routines Flexibility Path dependency
Zollo and Winter (2002)	A learned and stable pattern of collective activity Systematically generates and modifies organisational operating routines	Arising from learning Learning mechanisms are regarded as 'second-order' dynamic capabilities. Experience accumulation Knowledge articulation Knowledge codification	Dynamic
Adner and Helfat (2003)	Dynamic managerial capabilities The capabilities with which managers build, integrate, and reconfigure organisational resources and competences	Learning Learning-by-doing and require practice Managerial cognition	Dynamic
Blyler and Coff (2003)	Acquiring resources Integrating and recombining resources Releasing resources		Dynamic Flexibility Organic structure Simple routines Rigidities
Helfat and Peteraf (2003)	Dynamic capabilities consist of routines. Dynamic capabilities build, integrate, or reconfigure operational capabilities.	Learning Learning-by-doing	Dynamic
Sher and Lee (2004)	Decision quality Capabilities of communication and coordination Integration in new product development Capabilities of resource deployment Trust	Learning effectiveness of new knowledge Accumulation of knowledge	Enhanced responsiveness

As for the specific assets that Teece, Pisano and Shuen (1997) propose, we consider that they should not be included in the concept of dynamic capabilities. Specific assets, such as technological, structural, and reputational assets, are more similar to the concept of 'static' intellectual capitals than the concept of 'dynamic' capabilities. Eisenhardt and Martin (2000) have the resembling argument. They think that specific dynamic capabilities exhibit common features that are associated with effective processes across firms, i.e. the functionality of dynamic capabilities could be replicated due to the commonalities in key features of effective dynamic capabilities. They also consider that long-term competitive advantage lie in the resource configurations that managers build using dynamic capabilities, not in the capabilities themselves. From the above point of view, this research does not include specific assets in the concept of dynamic capabilities. As reviewing the primary researches related to dynamic capabilities, this research proposes that dynamic capabilities have three dimensions, including combinative capabilities, absorptive capacity, and flexibility.

2.2.1 Combinative capabilities

Looking at the content of Table 1, the first construct is concerning the concept of acquire, integrate, and reconfigure the internal and external knowledge, resources, and competences of the organisation. Kogut and Zander (1992) define combinative capabilities as the intersection of the capability of the firm to exploit its knowledge and the unexplored potential of the technology. After abstracting the meaning, this research names it as combinative capabilities (or integrative capabilities). In other words, innovations are often the results of utilising the firm's combinative capabilities to combine and reconfigure existing knowledge and resources for new applications. If we explore the content further, it comprises two sub-constructs, including knowledge and resources acquisition, and knowledge and resources integration.

1 *Knowledge and resources acquisition*: a firm's ability or processes to coordinate and integrate its network relationship inside and outside the organisation to acquire the knowledge, resources, and competences.

2 *Knowledge and resources integration*: a firm's ability or processes to reconfigure and transform these knowledge, resources, and competences that it acquired to generate new products and technologies.

2.2.2 Absorptive capacity

The second construct is concerning the concept of knowledge learning, assimilation, and internalisation. A firm can improve, deepen, expand, and accumulate its knowledge base as well as contributing to integrate and reconfigure internal and external knowledge, resources, and competences, through repeatedly practices, learning by doing, and the cooperation among strategic alliance partners. After abstracting the meaning, this research names it as absorptive capacity. If we explore the e-content further, it comprises three sub-constructs, including identification, learning, and efficiency of internal communication.

1 *Identification*: a firm's ability to recognise opportunities and crisis, search for new R&D directions, and evaluate the external new knowledge.

2 *Learning and absorption*: a firm's ability to setup learning mechanisms, and absorb the external knowledge effectively.

3 *Efficiency of internal communication*: a firm's ability to share and transfer the knowledge as well as internising it inside the organisation through the common specialised language.

2.2.3 Flexibility

The third construct is concerning the concept of flexibility and rigidity. While facing the challenges of new problems or the emerging new opportunities, managers have to make a correct and rapid respondance to the uncertainty of external environments. One of the necessary conditions is that the firm must have flexibility, if it wants to have this kind of ability to face these challenges (Georgsdottir and Getz, 2004). After abstracting the meaning, this research names it as flexibility. If we explore the e-content further, it comprises of two sub-constructs, including organisational and technological flexibility.

1 *Organisational flexibility*: The extent that a firm can adjust its routines and processes with flexibility to the changing environments.

2 *Technological flexibility*: The extent that a firm's members will not stick to their original professional fields.

3 Research framework and hypotheses

3.1 Combinative capabilities and innovative performance

Dynamic capabilities include the routines that coordinate the individual tasks. The need to coordinate tasks implies that a capability involves coordinated effort by individuals – teams (Helfat and Peteraf, 2003). The essential activities of teams are the combination and integration of individual knowledge into collective knowledge. In these activities, the most important issue to effectiveness of these teams is the knowledge combination, and integration processes. Okhuysen and Eisenhardt (2002) propose that formal interventions which focus on the important of the group process are a potential way to achieve superior knowledge integration, because they create a more structured group discussion, and enhance the communication of personally held information. Furthermore, resource recombination itself with how the knowledge embedded within a competence may have to be altered and integrated with other knowledge bases to create novel business concepts and/or competencies (Galunic and Rodan, 1998). Therefore, in order to encourage the interaction and communication among the internal members within the researches, the firm can hold face-to-face meeting regularly to promote a close interaction and profound discussion, so that the R&D members can share with other's knowledge and what one has learnt. Not only can this encourage the exchange, interflow, and collision of tacit knowledge, but also promote the knowledge combination and integration. Further, it can create brand-new ideas and concepts to improve its innovative performance. From the above discussion, we can obtain the following hypothesis.

Hypothesis 1: The combinative capabilities of a firm's R&D department have positive influences on its innovative performance.

3.2 Absorptive capacity and innovative performance

At the organisational level, a knowledge advantage is widely considered as a sustainable source of competitive advantage (Daghfous, 2004). And, learning effectiveness is an important factor influencing relationship performance of the firm's strategic alliance (Wu, Wu and Lo, 2006). Teece, Pisano and Shuen (1997) think that the capacity to reconfigure and transform is itself a learned organisational skill. The more frequently practiced the easier it is accomplished. They also consider that the term 'dynamic' refers to the capacity to renew competences so as to achieve congruence with the changing business environment. This means that in order to face the challenges of changing environment, a firm needs to keep on learning to update its knowledge and competences. Zollo and Winter (2002) emphasis that a dynamic capability is a learned and stable pattern of collective activity through which the organisation systematically generates and modifies its operating routine in pursuit of improved effectiveness, i.e. a firm's R&D department with dynamic capabilities has a good absorptive capacity so as to learn and assimilate knowledge effectively. Therefore, the more knowledge and competences the firm accumulates, the more it has the ability to create new products and technologies. The result is that it improves its innovative performance. From the above discussion, we can obtain the following hypothesis.

Hypothesis 2: The absorptive capacity of a firm's R&D department has positive influences on its innovative performance.

3.3 Flexibility and innovative performance

Simple routines and processes also play critical roles within a firm's innovation. Simple routines keep managers devoted themselves on broadly important issues without locking them into specific behaviours or the use of past experience that may be inappropriate or out of date given the actions required in a particular circumstance (Eisenhardt and Martin, 2000). Therefore, the R&D department with the higher dynamic capabilities can mobilise its R&D researchers promptly as well as adjust their working items flexibly, due to simple, experienced, and flexible operational routines and processes. As a result, the firm can respond to the rapidly changing environments, and generate the innovative outcomes matching the needs of the markets.

Furthermore, Leonard-Barton (1992) considers that although the organisation's core capabilities can enhance the firm's past development, they will probably lead to core rigidities for the needs of today's environments, so that they cannot create new and non-traditional capabilities, i.e. the members of R&D department might be used to their original professional fields rather than change to the other ones. This generates inertia. This kind of inertia lets the members of R&D department stick to their original professional fields, and then forms technological rigidity. On the other hand, the members of R&D department with dynamic capabilities have the courage trying to change their inertia and learn new technological knowledge fields. Low inertia and technological rigidity increase their flexibility which also facilitates responding to rapidly

changing environments to generate innovation. From the above discussion, we can obtain the following hypothesis.

Hypothesis 3: The flexibility of a firm's R&D department has positive influences on its innovative performance.

4 Step one: items generation

4.1 Research method

In order to confirm the factors' validity of dynamic capabilities, this research collected the data of firms' R&D departments from Taiwan and South Korea, and utilised a quantitative method to analyse the relationship between the R&D departments' dynamic capabilities of Korean firms and innovative performance. This research focuses on R&D departments of Enterprises. The definition of dynamic capabilities were examined and served as the basis for item generation. In addition, in order to understand the real practical situations, the researcher also interviewed 14 people, distributing over eight organisations, such as not-for-profit R&D organisations, science and engineering colleges in various universities, medical R&D organisation, and TFT-LCD company, to increase appropriate items. These people with practical experiences included nine males and five females from 25 to 55 years old, among them one high-level manager, nine mid-level managers, and four basic-level employees. The period of time is around 1.5–2.5 hours for each interview, depending on different interviewees. Based on the literature reviews and the results analysed from the interview data, the researchers wrote down the potential multiple items for each definition.

4.2 Content validity

The analysis of content validity can be divided into three steps. First, each item was discussed, respectively, among researchers, whether it can reflect the original sub-construct, and whether the meaning was clear. It would be deleted, if it were not appropriate. Besides, it would be revised, if the meaning were not clear enough causing misunderstanding or confusion. After deleting and revising some items, there were 64 ones remained in this step.

Next, the remaining items were examined by five Subject Matter Experts (SMEs). All these SMEs had doctoral degrees in the fields related to technology management and one of the five is a practical expert with 20 years of R&D experiences from the R&D organisation used for the field sample. The items were amended several times based on the feedback from these five experts. This resulted in 57 items with 7–9 items for each of the seven sub-constructs of dynamic capabilities.

Items were developed following the guidelines described by Hinkin (1998). Particularly, items were short and concise, they brought up a single issue, and they were worded positively to keep away from the potential psychometric problems with negative worded items (Schriessheim, Eisenbach and Hill, 1991). Besides, a response Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree, was used to ensure the consistency across items.

Finally, to ensure that the items were conceived as representing the seven sub-constructs, seven PhD students back-translated the 57 items onto the seven dimensions. Anderson and Gerbing (1991) suggest analysing this type of data for substantive validity. Substantive Agreement Index (SAI) is defined as the portion of respondents who choose a specific item to its intended construct. SAI value ranges from 0 to 1. The larger the values it has, the greater the portion of people choosing an item to his intended construct. If SAI$i \leq 0.5$ (i represents ith item), the item would be deleted. Using this method, after deleting some items, there were remaining 50 items, and SAI = 0.80. The result of SAI value revealed that the initial 50 items appeared to match the construct of dynamic capabilities. From the above description of three steps, the questionnaire developed by this research can achieve the requirement of content validity.

5 Step two: item reduction and reliability analysis

5.1 Research method

Although we did much of the efforts to confirm the content validity as mentioned above, we used Exploratory Factor Analysis (EFA) to further eliminate poor performing items with Statistical Package for the Social Science (SPSS). The sample in Step two was drawn from the EMBA and TIM[1] refreshing students in NCCU,[2] Taiwan. These respondents had the working experiences of at least two years and were sieved out severely by NCCU. The overwhelming majority was mid- or high-level managers with a good competence, and was regarded highly for their companies or led the company's future development, i.e. they were appropriate samples for this research, because they quite understood the company's operations.

5.2 Results

The questionnaire was administered to 198 EMBA and TIM students. One hundred and eleven of them completed the survey with 50 items in it. The response rate was 56.1%. Of the respondents, 76.8% were men; 28.6% had undergraduate degree, 61.2% had master degree, 8.2% had PhD; average age was 40.5; average working experiences in their companies were 7.5 years; 21.4% were in electronic industry, 14.3% were in IT industry, 10.2% were in telecommunication industry, 15.3% were in biotech and medical industries, 6.1% were in traditional industry.

Principal axis factoring analysis with orthogonal rotation was performed on the 50 items using SPSS factor analysis. Based on some criteria, such as eigenvalues (eigenvalues ≥ 1) and interpretability of factors, an eight-factor solution was selected. Among these factors, 'knowledge and resources acquisition' split into two factors, including 'internal knowledge and resources acquisition' and 'external knowledge and resources acquisition'. 'Knowledge and resources acquisition' being two factors rather than the one consistent with existing theory as explained by Teece, Pisano and Shuen (1997) and Eisenhardt and Martin (2000), i.e. 'knowledge and resources acquisition' is conceptualised as having both content and predictive validity of two components. After deleting some items, there were 29 items retained and eight factors accounted for 61.42% of the variance in the items. These eight factors were internal knowledge and resources acquisition (four items), external knowledge and resources acquisition (four items),

knowledge and resources integration (four items), identification (four items), learning (three items), efficiency of internal communication (three items), organisational flexibility (three items), and technological flexibility (four items). All items loaded on their appropriate factor (> 0.40).

All subscales showed sufficient reliability for a new scale with alpha coefficients, including 0.75 for internal knowledge and resources acquisition (n = 111, factor 1), 0.79 for external knowledge and resources acquisition (n = 110, factor 2), 0.85 for knowledge and resources integration (n = 110, factor 3), 0.86 for identification (n = 110, factor 4), 0.83 for learning (n = 111, factor 5), 0.78 for efficiency of internal communication (n = 111, factor 6), 0.71 for organisational flexibility (n = 109, factor 7), and 0.86 for technological flexibility (n = 108, factor 8). These alpha coefficients surpass the acceptable level of 0.70 for newly developed scales (Nunnally, 1978). Factor intercorrelation ranged from 0.18 to 0.62 as shown in Table 2.

The results provided evidence for the eight-factor structure and internal consistency of the subscales. We next tested the scale using Confirmatory Factor Analysis (CFA) and a new sample of respondents.

Table 2 Intercorrelation coefficients of eight factors

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*	*Factor 6*	*Factor 7*	*Factor 8*
Factor 1	1.00							
Factor 2	0.45***	1.00						
Factor 3	0.44***	0.53***	1.00					
Factor 4	0.43***	0.47***	0.62***	1.00				
Factor 5	0.32***	0.32***	0.52***	0.55***	1.00			
Factor 6	0.24**	0.21*	0.42***	0.49***	0.32***	1.00		
Factor 7	0.24**	0.18*	0.32***	0.24**	0.26**	0.20*	1.00	
Factor 8	0.23**	0.20*	0.46***	0.46***	0.28**	0.43***	0.30***	1.00

*p < 0.05 , **p < 0.01, ***p < 0.001.

6 Step three: confirmatory factor analysis

6.1 Research method

According to the developing steps of scale by Hinkin (1998), we needed to confirm the construct validity by CFA with another sample. The sample in Step three was drawn from the MBA students in KAIST[3], South Korea. The remaining 29 items were translated into both English and Korean languages. After our checking without mistakes, we delivered three versions of questionnaire, including English, Chinese, and Korean, to two Korean people with excellent Chinese and English communication ability to revise the final Korean version. Moreover, in the process of revisal, researcher closely kept up interactions and discussions with them to make sure of the wordings with accuracy and appropriateness.

Researcher spent four months from March to June in 2006, staying in KAIST to collect the data. There are several reasons for utilising KAIST MBA as the sample group. First, these full time MBA students have working experiences for at least two years – most of them have 5–6 years. Secondly, around 70–80% of them were supported financially by their companies, including the tuition fee and still having the salary for

every month. Some of them said that they had to submit the reports back to the company by semester. Thirdly, all of them had very good working performance and were sieved out strictly by their companies as a critical person they would like to cultivate, so that they could have the opportunity to enter KAIST, one of the best management schools in South Korea. In other words, they were not only affirmed as persons with competences, but they also understood the operation of their companies. Therefore, they are the appropriate sample group for our research.

6.2 Results

Through the help of 20 assistants, the questionnaire was administered to 165 KAIST MBA students. One hundred and thirty eight of them completed the survey with 29 items in it. The response rate was 83.6%. Of the respondents, 72.5% were men; 58% had undergraduate degree, 42% had master degree; average age was 31.6; average working experiences in their companies were 5.2 years; 24.8% were in electronic industry, 26.4% were in IT industry, 7.0% were in telecommunication industry, 2.3% were in biotech and medical industries, 7.0% were in traditional industry.

A CFA was conducted to test the goodness of fit by using LISREL 8.51 version as analysis tool (Jöreskog and Sörbom, 1993). We utilised Maximum Likelihood Estimation to estimate the parameters to figure out its goodness of fit, and then analysed the convergent validity and discriminate validity. This research adopted some indices, such as Goodness-of-Fit Index (GFI), Comparative Fit Index (CFI), and Incremental Fit Index (IFI), to determine the goodness of fit, because the χ^2 statistic is easily affected by the sample size. The results showed that $\chi^2 = 534.19$, d.f. = 349, $p < 0.001$, χ^2/d.f. = 1.53. Furthermore, the Root Mean Square Error of Approximation (RMSEA) = 0.053 and the values of goodness of fit were Non-normed Fit Index (NNFI) = 0.85, CFI = 0.87, IFI = 0.88, and GFI = 0.80. From the above results, the goodness of fit was not good enough for eight factors with 29 items, and there was a room for improvement.

In order to improve the goodness of fit, this research deleted some items according to Modification Index (MI). After that, there were 21 items remaining in the questionnaire. The items are listed in Appendix. This research conducted CFA of eight-factor model again. The results showed that $\chi^2 = 200.06$, d.f. = 161, $p < 0.05$, χ^2/d.f. = 1.24. Moreover, NNFI = 0.95, CFI = 0.96, IFI = 0.96, and GFI = 0.89. Except GFI was a little bit lower than 0.9, others were higher than 0.9, which is suggested by Hair et al. (1998). This reveals that the goodness of fit is excellent for the eight-factor model. RMSEA value of < 0.080 indicates a good fitting model (Hair et al., 1998).

6.3 Convergent validity

Table 3 shows the values of Lambda-X, SE, and *t* for each item. The *t*-value of every item is far > 1.96 and significant which means that all the values of Lambda-X are statistically meaningful. Moreover, the factor loadings are 0.50–0.89, which are all > 0.50 that was suggested by Fornell and Larcker (1981). This reveals that the questionnaire of this research has excellent convergent validity.

Table 3 Lambda-X, SE, and *t*-value of each item

1 Internal knowledge and resources acquisition	*A1*	*A2*	*A3*
Lambda-X	0.66	0.78	0.50
SE	0.09	0.09	0.09
t-Value	7.24	8.57	5.39
2 External knowledge and resources acquisition	*B1*	*B2*	*B3*
Lambda-X	0.79	0.78	0.79
SE	0.08	0.08	0.08
t-Value	9.95	9.78	9.93
3 Knowledge and resources integration	*C1*	*C2*	
Lambda-X	0.69	0.89	
SE	(0.09)	(0.09)	
t-Value	8.12	10.44	
4 Identification	*D2*	*D3*	*D4*
Lambda-X	0.58	0.70	0.76
SE	0.09	0.09	0.08
t-Value	6.50	8.19	8.98
5 Learning	*E2*	*E3*	
Lambda-X	0.63	0.59	
SE	0.09	0.09	
t-Value	6.68	6.31	
6 Efficiency of internal communication	*F2*	*F3*	*F4*
Lambda-X	0.79	0.85	0.80
SE	0.08	0.07	0.08
t-Value	10.40	11.55	10.72
7 Origination flexibility	*G2*	*G3*	*G4*
Lambda-X	0.76	0.76	0.67
SE	0.08	0.08	0.08
t-Value	9.33	9.35	8.01
8 Technological flexibility	*H2*	*H4*	
Lambda-X	0.78	0.57	
SE	0.10	0.09	
t-Value	7.69	6.00	

6.4 Discriminate validity

Phi value represents the relationship between constructs. The discriminate validity of eight factors can be tested from the Phi values listed in Table 4. Utilising the rule of correlation coefficient plus and minus two SEs, if the value involves one, this means that it cannot distinguish the two constructs. The results showed that the values were from –0.04 to 0.98, and no one involved one, i.e. these eight factors are not the same constructs. Therefore, this research confirms the existence of discriminate validity.

Table 4 Phi value

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*	*Factor 6*	*Factor 7*	*Factor 8*
Factor 1	1.00							
Factor 2	**0.24**	1.00						
	0.11							
	2.30							
Factor 3	**0.30**	**0.25**	1.00					
	0.10	0.10						
	2.84	2.52						
Factor 4	**0.18**	**0.29**	**0.27**	1.00				
	0.11	0.10	0.10					
	1.58	2.80	2.65					
Factor 5	**0.49**	**0.40**	**0.48**	**0.80**	1.00			
	0.12	0.12	0.11	0.09				
	4.00	3.37	4.19	8.48				
Factor 6	**0.38**	**0.19**	**0.61**	**0.33**	**0.39**	1.00		
	0.10	0.10	0.07	0.10	0.12			
	3.85	1.90	8.10	3.31	3.36			
Factor 7	**0.59**	**0.29**	**0.57**	**0.29**	**0.42**	**0.52**	1.00	
	0.09	0.10	0.08	0.11	0.12	0.08		
	6.76	2.91	6.84	2.72	3.48	6.36		
Factor 8	**0.39**	**0.36**	**0.34**	**0.53**	**0.63**	**0.52**	**0.48**	1.00
	0.11	0.11	0.11	0.10	0.12	0.10	0.10	
	3.42	3.34	3.11	5.03	5.06	5.48	4.64	

7 Step four: hypotheses testing

7.1 Research method

Regression analysis was conducted by using SPSS to test the relationship between R&D department's dynamic capabilities and innovative performance for both Taiwanese and Korean samples. As for the missing data, this research used exclude cases list wise function of SPSS to deal with them.

7.1.1 Independent variables

This research used the dynamic capabilities of R&D department as independent variables, including combinative capabilities, absorptive capacity, and flexibility. Three sub-scales with eight items were used to measure the combinative capabilities. Next, three sub-scales with eight items were used to measure the absorptive capacity. Finally, two sub-scales with five items were used to measure flexibility. The items are listed in Appendix (Part A).

7.1.2 Dependent variables

This research used the innovative performance of R&D department as dependent variable. One sub-scale with two items was used to measure innovative performance as listed in Appendix (Part B).

7.1.3 Control variables

There were two control variables in this research, including company scale and R&D scale. Generally speaking, innovation expenditure with labour and capital has a significant influence on the value of research output (Subrahmanya, 2006). Considering that company scale and R&D scale might strongly affect innovative performance of R&D department, thus we used them as control variables. This research utilised 'total number of company employees' and 'total number of R&D employees' as proxies to represent 'company scale', and 'R&D scale', respectively.

7.2 Results

Table 5 provides the mean, SD, and correlation of all the continuous variables included in this research. There are positive correlations between every two variables. In addition, most of them are statistically significant.

Table 5 Mean, SDs, and correlations among variables

Variables	*Average value*	*SD*	*1*	*2*	*3*	*4*	*5*
Taiwan							
1 Innovative performance	3.53	0.82					
2 R&D scale	401.17	1139.63	0.20*				
3 Company scale	4484.67	8541.51	0.13*	0.69***			
4 Combinative capabilities	3.46	0.60	0.49***	0.25**	0.26**		
5 Absorptive capacity	3.54	0.62	0.54***	0.30**	0.27**	0.65***	
6 Flexibility	3.60	0.56	0.53***	0.03	0.09	0.41***	0.48***
Korea							
1 Innovative performance	3.37	0.81					
2 R&D scale	2120.08	9850.90	0.23**				
3 Company scale	12282.92	36047.23	0.23*	0.34***			
4 Combinative capabilities	3.27	0.52	0.32***	0.13†	0.11		
5 Absorptive capacity	3.49	0.51	0.41***	0.18*	0.10	0.48***	
6 Flexibility	3.31	0.61	0.43***	0.16*	0.15†	0.54***	0.57***

Notes: † Significant at $p < 0.1$; * Significant at $p < 0.05$; ** Significant at $p < 0.01$; *** Significant at $p < 0.001$.

Table 6 shows the results of regression analysis, including two clusters, the results of Taiwanese (T) and South Korean (K) samples. For the sample of Taiwan, first, the adjusted R^2 for Model T1, which explained the relationship between control variables and innovative performance, is 0.02. Secondly, Model T2 is statistically significant (adjusted R^2=0.38, $p < 0.001$). The results show that it has a significant effect of absorptive

capacity on innovative performance ($\beta = 0.23$, $p < 0.05$), and does support Hypothesis 2. Moreover, it has a significant effect of flexibility on innovative performance ($\beta = 0.35$, $p < 0.001$), and does support Hypothesis 3. As for Hypothesis 1, the results show that it has a significant effect of combinative capabilities on innovative performance under the level of $p < 0.1$ ($\beta = 0.19$), and support Hypothesis 1. Finally, comparing Model T1 and T2, when the independent variables, combinative capabilities, absorptive capacity, and flexibility, are added to the regression (as shown in Table 6), it explains marginally a significant amount of variability, $\Delta R^2 = 0.36$, in innovative performance beyond that of the control variables ($p < 0.001$).

Table 6 Results of regression analysis for both Taiwanese and Korean samples

	Taiwan		*South Korea*	
Variables	*Model T1*	*Model T2*	*Model K1*	*Model K2*
Control variables				
R&D scale	0.20	0.15	0.17†	0.10
Company scale	0.01	0.12	0.17†	0.13
Independent variables				
Combinative capabilities		0.19†		0.06
Absorptive capacity		0.23*		0.20†
Flexibility		0.35***		0.25*
Model F	1.93	13.29***	4.30*	7.07***
R^2	0.04	0.41	0.08	0.26
Adjusted R^2	0.02	0.38	0.06	0.22
ΔAdjusted R^2		0.36		0.16

Dependent variable: innovative performance

Notes: † Significant at $p < 0.1$; *Significant at $p < 0.05$; **Significant at $p < 0.01$; *** Significant at $p < 0.001$.

Coefficients are standardized beta weights.

As for the sample of South Korea, first, Model K1, which explained the relationship between control variables and innovative performance, is statistically significant (adjusted $R^2 = 0.06$, $p < 0.05$). Secondly, Model K2 is also statistically significant (adjusted $R^2 = 0.22$, $p < 0.001$). The results show that it has a significant effect of absorptive capacity on innovative performance under the level of $p < 0.1$ ($\beta = 0.20$), and support Hypothesis 2. Moreover, it has a significant effect of flexibility on innovative performance ($\beta = 0.25$, $p < 0.05$), and does support Hypothesis 3. However, the results show that it has not a significant effect of combinative capabilities on innovative performance ($\beta = 0.06$, $p > 0.1$), and does not support Hypothesis 1. Finally, comparing Models K1 and K2, when the independent variables, combinative capabilities, absorptive capacity, and flexibility, are added to the regression (as shown in Table 6), it explains a marginally significant amount of variability, $\Delta R^2 = 0.16$, in innovative performance beyond that of the control variables ($p < 0.001$).

8 Discussion

8.1 The generalisation of dynamic capabilities questionnaire

This research used the samples of both Taiwan and South Korea to develop the questionnaire of R&D department's dynamic capabilities. The results showed that it contains three sub-constructs (combinative capabilities, absorptive capacity, and flexibility) and eight factors, totally 21 items. This research provided the evidences of reliability and validity for our model. The values of Cronbach's alpha were all > 0.70, which fit in with the requirement of reliability. This research also provided the analysis of content validity, which was divided into three steps. Besides, the results of fit of goodness were higher than 0.90, except GFI that was equal to 0.89. And, RMSEA for the model was 0.034. These indicate a good fit of model to the data. Moreover, the loading factors of 21 items were from 0.50 to 0.89, indicating that the questionnaire of this research had good convergent validity. In addition, according to PHI values, these eight factors were not the same constructs, which fit in with the requirement of discriminate validity. From the above results, this questionnaire of dynamic capabilities for R&D department with three dimensions and 21 items, developed from the samples from Taiwan and South Korea, had a good reliability and validity.

8.2 Innovative performance and dynamic capabilities of business R&D department

This research used Taiwanese and South Korean samples to test the relationship between R&D department's dynamic capabilities and innovative performance. Both of the results supported Hypotheses 2 and 3, i.e. the absorptive capacity and flexibility of business R&D department are the important forecasting factors for innovative performance. In other words, if the R&D department can enhance its absorptive capacity and flexibility, it can effectively improve its dynamic capabilities to increase its innovative achievements and promptly introduce new products that fit customers' needs into markets under rapidly changing and unanticipated environments.

As for Hypothesis 1, the results from both the samples were not consistent. It was supported by the results of Taiwanese sample under the level of $p < 0.1$. However, it was not supported by the results of South Korean sample. This means that the relationship between the R&D department's combinative capabilities and the innovative performance is still vague and worth further exploring. From the point of both theoretical and practical view, a business with appropriate competences and capabilities can properly make use of the knowledge inside and outside the company, reconfiguring and integrating them to generate innovation. The better the combintive capabilities a company has, the better the business can enhance the utilisation of knowledge and technologies. And the better it has the availability to generate innovation through recombination and reconfiguration. Therefore, Hypothesis 1 should be supported from the point of both theoretical and practical view. Nevertheless, why were the results inconsistent? Perhaps, the reason was resulted from the existence of other moderators so as to affect the relationship. In this case, the moderator might be 'industrial structure', which may be distinct due to different countries. In Taiwan's industries, extremely most of the enterprises are small and medium businesses. Each company runs its business in a small area due to limited resources. In order to survive and compete with their competitors that are much stronger

than them in the world, they have no choice but to form partnership with solid network. For example, in Taiwan's personal computer or laptop industry, it was composed of hundreds of electronic companies, working together on this single product but doing different parts. Even though each company is specialised in only one particular part, but through collective efforts they could finally manufacture the whole product with a low cost and a good quality, and even be faster and more flexible than their competitors. In this entire industry, they mutually relied on and trusted in each other, due to relativeness, close friendship, or cooperation for a long time. Therefore, this kind of industrial structure provided a good environment for them to acquire the external knowledge as well as to integrate and recombine the knowledge from inside and outside of the company. This facilitated the generation of innovation. Under the influence of the moderator, industrial structure, it might lead to the results that are dependent upon different situations. However, we need a further exploration and get more evidence to confirm this inference in the next phase of study.

Overall, Hypotheses 2 and 3 were supported by both the results from these two countries' samples, and Hypothesis 1 was supported by the results of Taiwanese sample. Therefore, the results supported our main argument that the dynamic capabilities of R&D department have positive influences on its innovative performance.

9 Conclusion

After reviewing the papers of dynamic capabilities and referring to their definitions, this research studied the measuring dimensions and the tool of dynamic capabilities. Four separate steps of research were conducted. Step one involved item generation and provided the processes of checking the content validity. Step two involved preliminary item reduction through EFA of data collected from the EMBA and TIM refreshing students in NCCU, Taiwan, and provided the evidence of reliability. Step three used another sample of MBA students in KAIST, South Korea, to confirm the factor structure by providing the good fit of the model, convergent and discriminate validity evidences for the questionnaire. Step four used these two diverse samples collected from Taiwan and South Korea to test three hypotheses. Results of the four steps showed that there were three sub-constructs and eight factors for R&D department's dynamic capabilities. The results demonstrated that the questionnaire with 21 items achieves the acceptable quality to measure R&D department's dynamic capabilities. In addition, the results showed that R&D department's combinative capabilities, absorptive capacity, and flexibility are critical forecasting factors for innovative performance, i.e. if the business can enhance R&D department's combinative capabilities, absorptive capacity, and flexibility, it can improve its dynamic capabilities and increase its innovative results with effectiveness under rapidly changing and unexpectable environments. However, it also showed that there might have other moderators, such as industrial structure, to affect the relationship between combinative capabilities and innovative performance, due to the distinct results of separate surveys from Taiwan and South Korea. But, this inference must be further explored and confirmed in the next phase of study.

The development of dynamic capabilities questionnaire has theoretical implication. Although Teece, Pisano and Shuen (1997), Eisenhardt and Martin (2000), Zollo and Winter (2002) did not differentiate these three sub-constructs and eight factors in their researches, this study provided the reliability and validity evidences for the three

sub-construct and eight factor model with 21 items to measure the dynamic capabilities. In other words, this research provides definite items as a reference for measuring dynamic capabilities. This will be contributive to the future study in this filed.

The development of dynamic capabilities questionnaire has several practical implications. First, due to the explicit items generated by this research, the business managers can measure their dynamic capabilities of R&D department to figure out which parts of capabilities should be improved so as to have a better innovative performance.

Secondly, enhancing how to acquire and integrate resources and knowledge from inside and outside of the company is a critical way to improve innovative performance. Managers should keep on establishing and maintaining partnerships with other companies or institutes. Generally, it is not easy to acquire or learn other company's implicit knowledge without good relations of partnership or cooperation. Only if setting up long-term relationships and having trust in each other, can interfirm's knowledge flow become possible. Moreover, the combination of different basic scientific knowledge is the key successful factor in the future research. Therefore, managers should recruit R&D researchers from various knowledge backgrounds, which help the R&D members to think differently and inspire innovation when they discuss and exchange opinions. In addition, in order to help the internal staff's interaction and brain storming, managers can hold regular and face-to-face meetings to facilitate cross-boundary and heterogeneous knowledge discussion and integration. All these ways can improve company's combinative capabilities, and then enhance its innovative performance.

Thirdly, learning is a good way to improve absorptive capacity. The proper management of knowledge can create an organisational learning environment that improves and creates competitive advantages for a business organisation as it responds to today's business demands in a much more dynamic environment (Melton, Chen and Lin, 2006). Arranging various learning programmes for employees is one of the possible ways, such as an on-the-job training and other particular specialised courses. Learning is also a good way to facilitate the leaders identifying the correct R&D directions. Without continuous learning, the leaders can neither have the capability to accurately evaluate the trend of developing technologies in the rapidly changing environments, nor can they determine the information and knowledge needed by certain development projects. Besides, through systematically and periodically updating knowledge database, the firm can provide the sources of extensive knowledge and information for R&D leaders to recognise and judge future R&D directions. Moreover, enhancing the interactions and communications among the employees is another important way to improve organisation's absorptive capacity. Except formal meeting to discuss for solving the problems, managers can create a nice, real, and substantial place in the company for employees to linger and discuss without restrictions while they are free. This can facilitate the implicit knowledge transfer and sharing, not just amass knowledge in several superior individuals, and then improve organisation's absorptive capacity. Job rotation is also a good way to improve the degree and efficiency of communication, because employees can learn skills and knowledge in a new field as well as realise the other people's situations and mental state while they actually participate in the new job.

Finally, it is critical for the firm to improve its dynamic capabilities through flexibly adjusting routines and processes. When unexpected factors surface and must flexibly amend the initial direction of research, high-level management should support the R&D teams highly with various resources that they need. However, flexibly changing the organisation's processes and R&D directions will raise the operation risks and

obstruction. Some factors, such as sticking at the original technological field, learning obstacles, or vested interests in the firm, will often lead to a huge resistance from employees for flexible adjustment. Therefore, managers should consider in advance how to deal properly with all kinds of complicated situations. There are several possible ways, including appropriate communication and explanation with employees in advance of why we need to adjust, arrangement of learning opportunity so as to decrease the obstacles while employees need to switch to other technological field, or negotiating with employees to exchange something of value for an agreement to lessen the resistance to the change effort.

This study has potential limitations that should be noted. Although this research used two samples from both Taiwan and South Korea to develop three construct and eight factor model, however, there are several reasons we need to confirm the questionnaire's generaliability. First, Taiwan and South Korea have similar geographical features of Asian countries. Secondly, they belong to the developing countries having almost the same living standard. Finally, these two countries were profoundly affected by China culture in the past years, and the customs between the two countries are much closer comparing with those of the European or American countries. Therefore, if any of the researchers want to apply this questionnaire to the circumstances of developed areas, they should consider the generaliability in those countries. In addition, in the process of doing this research, we hope we can get the objective data of innovative performance from the Taiwan and Korean enterprises. Nevertheless, there were difficulties and restrictions existed, especially a transnational survey. Therefore, the data of innovative performance were filled out by respondent's subjective perception. In other words, there might generate the problems of common method variance, due to all the items filled out by single respondent. This is a point that could be improved in the future study.

Areas for future research might include:

1 testing the relationship between the R&D department's dynamic capabilities and the innovative performance by using the sample of developed countries to extend the questionnaire's generaliability

2 exploring the existence of other moderators to further clarify the relationship between the combinative capabilities and the innovative performance.

Reference

Adner, R. and Helfat, C.E. (2003) 'Corporate effects and dynamic managerial capabilities', *Strategic Management Journal*, Vol. 24, pp.1011–1025.

Anderson, J.C. and Gerbing, D.W. (1991) 'Predicting the performance of measures in a confirmatory factor analysis with a pretest assessment of their substantive validates', *Journal of Applied Psychology*, Vol. 76, pp.732–740.

Ahsan, M.J.F.F., Kumara, P.A.P.S. and Herath, S.K. (2007) 'The Country image effects on the milk power market of southern region in Sri Lanka', *Int. J. Management and Enterprise Development*, Vol. 4, pp.82–95.

Blyler, M. and Coff, R.W. (2003) 'Dynamic capabilities, social capital, and rent appropriation: ties that split pies', *Strategic Management Journal*, Vol. 24, pp.677–686.

Daghfous, A. (2004) 'Knowledge management as an organizational innovation: an absorptive capacity perspective and a case study', *Int. J. Innovation and Learning*, Vol. 1, pp.409–422.

Eisenhardt, K.M. and Martin, J.A. (2000), 'Dynamic capabilities : what are they', *Strategic Management Journal*, Vol. 21, pp.1105–1121.

Fornell, C. and Larcker, D.F. (1981) 'Evaluating structural equation models with unobservable variables and measurement error', *Journal of Marketing Research*, Vol. 18, pp.39–50.

Galunic, D.C. and Rodan, S. (1998) 'Resource recombination in the firm: knowledge structures and the potential for Schumpeterian innovation', *Strategic Management Journal*, Vol. 19, pp.1193–1201.

Georgsdottir, A.S. and Getz, I. (2004) 'How flexibility facilitates innovation and ways to manage it in organizations', *Creativity and Innovation Management*, Vol. 13, pp.166–175.

Hair, J.F. Jr., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998) *Multivariate Data Analysis* (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Helfat, C.E. and Peteraf, M.A. (2003) 'The dynamic resource-based view: capability lifecycles', *Strategic Management Journal*, Vol. 24, pp.997–1010.

Hinkin, T.R. (1998) 'A brief tutorial on the development of measures for use in survey questionnaires', *Organization Research Methods*, Vol. 1, pp.104–121.

Hsu, R.C., Lawson, D. and Lin, B. (2007) 'Factors affecting knowledge adoption of Taiwan small and medium-sized enterprises', *Int. J. Management and Enterprise Development,* Vol. 4, pp.30–51.

Jöreskog, K.G. and Sörbom, D. (1993) *LISREL 8 User's Reference Guide*, Chicago: Scientific Software.

Kogut, B. and Zander, U. (1992) 'Knowledge of the firm combinative capabilities and the replication of technology', *Organization Science*, Vol. 3, pp.383–397.

Leonard-Barton, D. (1992) 'Core capabilities and core rigidities: a paradox in managing new product development', *Strategic Management Journal*, Vol. 13, pp.111–125.

Lubitz, D.V. and Wickramasinghe, N. (2006) 'Creating germane knowledge in dynamic environments', *Int. J. Innovation and Learning*, Vol. 3, pp.326–347.

Melton, C.E., Chen, C.H. and Lin, B.S. (2006) 'Organisational knowledge and learning: leveraging it to accelerate the creation of competitive advantages', *Int. J. Innovation and Learning*, Vol. 3, pp.254–266.

Nunnally, J.C. (1978) *Psychometric Theory*. New York, NY: McGraw-Hill.

Okhuysen, G.A. and Eisenhardt, K.M. (2002) 'Integrating knowledge in groups: how formal interventions enable flexibility', *Organization Science*, Vol. 13, pp.370–386.

Schriessheim, C.A., Eisenbach, R.J. and Hill, K.D. (1991) 'The effect of negation and polar opposite item reversals on questionnaire reliability and validity: an experimental investigation', *Education and Psychological Measurement*, Vol. 51, pp.67–74.

Sher, P.J. and Lee, V.C. (2004) 'Information technology as a facilitator for enhancing dynamic capabilities through knowledge management', *Information & Management*, Vol. 41, pp.933–945.

Subrahmanya, M.H. (2006) 'Technological innovations in Indian Small and Medium Enterprises (SMEs) sector: does firm size matter?', *Int. J. Innovation and Learning*, Vol. 3, pp.499–517.

Teece, D.J. (1984) 'Economic analysis and strategic management', *California Management Review*, Vol. 26, pp.87–110.

Teece, D.J., Pisano, G. and Shuen, A. (1997) 'Dynamic capabilities and strategic management', *Strategic Management Journal*, Vol. 18, pp.509–534.

Teswanich, W., Anutariya, C. and Wiuwongse, V. (2006) 'A knowledge management system framework for government regulating processes', *Electronic Government: An International Journal,* Vol. 3, pp.56–73.

Wei, J., Platt, R., White, B. and Jasquith, A.P. (2006) 'Development of standardised e-business solutions via e-chain analysis in the digital utility', *Int. J. Services and Standards*, Vol. 2, pp.117–136.

Wernerfelt, B. (1984) 'A resourced-based view of the firm', *Strategic Management Journal*, Vol. 5, pp.171–180.

Wickramasighhe, N. (2006) 'Knowledge creation: a meta-framework', *Int. J. Innovation and Learning*, Vol. 3, pp.558–573.

Wickramasighhe, N. (2007) 'Fostering knoweldge assets in healhcare with the KMI model', *Int. J. Management and Enterprise Development*, Vol. 4, pp.52–65.

Williamson, O.E. (1999) 'Strategy research: governance and competence perspective', *Strategic Management Journal*, Vol. 20, pp.1087–1108.

Wu, W.Y., Wu, Y.J. and Lo, Y.J. (2006) 'The impact of governance mechanisms on interfirm learning and relationship performance', *Int. J. Innovation and Learning*, Vol. 3, pp.673–691.

Zollo, M. and Winter, S.G. (2002) 'Deliberate learning and evolution of dynamic capabilities', *Organization Science*, Vol. 13, pp.339–351.

Appendix: Questionnaire

Part A: Questionnaire of dynamic capabilities

A Combinative capabilities

(1) Internal knowledge and resources acquisition

1 The R&D department of you company can easily obtain needed technologies and knowledge internal of the organisation.

2 The R&D department of you company can easily obtain needed assistances from technical personnel internal of the organisation.

3 The R&D department of you company can easily obtain needed assistances from the marketing personnel of the organisation.

(2) External knowledge and resources acquisition

1 The R&D department of you company can easily obtain needed technologies and knowledge external of the organisation.

2 The R&D department of you company can easily obtain needed assistances from technical personnel external of the organisation.

3 The R&D department of you company can easily obtain or use the needed equipments and instruments external of the organisation.

(3) Knowledge and resources integration

1 Colleagues in the R&D department always can brainstorm out some good ideas during discussions.

2 The R&D department effectively integrates knowledge internal as well as external of the company.

B Absorptive capacity

(1) Identification

1 The R&D department regularly updates and accumulates the knowledge pool.

2 The R&D department has the capability to determine which are the information and knowledge needed by certain development projects.

3 The R&D department has the capability to accurately evaluate the importance of new knowledge and new technologies.

(2) Learning

1 The R&D department has the reward system for the colleagues to further their knowledge.

2 The R&D department frequently arranges programmes of new knowledge and new technologies for colleagues in this department.

(3) Efficiency of internal communication

1 Colleagues of the R&D department are patient in listening to opinions of others.

2 When discussing, colleagues of the R&D department are often capable of understanding others.

3 When discussing, colleagues of the R&D department often come to consensuses when differences in opinions arise during discussion.

C Flexibility

(1) Organisational flexibility

1 Rules set by the R&D management for new product development proposals and investments may be adjusted to respond to situations.

2 High-level management of the R&D department support flexible changes in the organisation's routines.

3 When unexpected factors surface and must flexibly amend the initial direction of research, high-level management of the R&D department support the R&D teams highly with various resources that they need.

(2) Technological flexibility

1 When the external environment changes, colleagues of the R&D department are willing to switch from their original technical fields and learn new knowledge and technologies.

2 Other than professional knowledge, colleagues of the R&D department are also interested in knowledge of other fields.

Part B: Questionnaire of innovative performance

1 Overall, the R&D department is capable of timely responding to the changing environments and developing new technologies that meet the market demands.

2 Overall, the R&D department is capable of timely responding to the changing environments and developing new products that meet the market demands.

Notes

[1]TIM: The graduate school of Technology and Innovation Management.

[2]NCCU: National Cheng-Chi University, Taiwan.

[3]KAIST: Korean Advanced Institute of Science and Technology.