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**Article**

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## MANAGEMENT | REVIEW ARTICLE

# Knowledge exchange types and strategies on the innovation interactions between KIBS firms and their clients in Taiwan

Tai-Shan Hu<sup>1\*</sup>, Cheng-Wei Yu<sup>2</sup> and Ping-Ching Chia<sup>3</sup>

**Abstract:** This investigation discusses the innovative activities of Knowledge-Intensive Business Services (KIBS) in the developmental process. To improve understanding of KIBS, the study aims to understand empirically the functions and mechanisms of knowledge intermediaries in different organizations and developmental processes, and also explores knowledge exchange and factors affecting KIBS. This study performs an empirical analysis of KIBS based on a recent manufacturer survey and emphasizes the connections among KIBS, innovation and forms of knowledge. The research results indicate the following conclusions: (1) Taiwanese KIBS enterprises tend to exchange knowledge with clients through mixed and codified knowledge; (2) firms that rely mainly on the exchange of codified knowledge have improved connections with clients, technologies, research innovation and application of advanced technologies; (3) enterprises mainly exchange mixed knowledge, and focus on knowledge management and information sources required during innovation processes, and (4) fewer enterprises exchange knowledge through tacit knowledge. The research implication is that enterprises emphasize different factors based on different types of knowledge exchange and services.

### ABOUT THE AUTHOR

Professor Tai-Shan Hu currently works at the Department of Urban Planning, National Cheng Kung University, Taiwan. He has been focusing on the field of urban and regional planning, analysis and planning of industrial environment, as well as knowledge-based industries and urban development for years. His passion is to engage into the research of knowledge intensive industries and contribute to the academic world has driven him to keep excavating the research topic related to industrial development. His key research activities include publishing periodical papers, conference papers and books, taking the responsibility to be the principal investigator of governmental and corporate research, and finally giving back his professional knowledge earned from the research activities to his teaching. This is an innovative research that tried to supplement the global research gap of KIBS which exchange three kinds of knowledge, namely the mixed, codified and tacit knowledge, through conducting an empirical experiment in Taiwan

### PUBLIC INTEREST STATEMENT

The purchasing behavior of purchaser is not simply buying and selling, but relates to the corporate operating to produce to satisfy their needs. In fact, there are interactions between corporates to buy and sell material, information, technology or knowledge, through which an incentive is provided to improve knowledge or technology, before a provision of goods or services we enjoy. This study is to comprehend the interactions between firms in Taiwan, through which they shared three types of knowledge with each other, including tacit knowledge (understanding stored in a person's head), codified knowledge (explicit and systematized knowledge) and mixed knowledge (both the tacit and codified knowledge). The research results suggest that in Taiwan, the firms tend to exchange mixed and codified knowledge with clients and a few of them exchange tacit knowledge. Interestingly, the purchasing behavior has triggered corporate interactions to supply items that better suit their needs through a knowledge exchange.

**Subjects: Urban Studies; Development Policy; Industry & Industrial Studies**

**Keywords: knowledge exchange; innovation interactions; knowledge-intensive business services**

## 1. Introduction

The Knowledge-Intensive Business Services (KIBS) sector is one of the fastest growing economic sectors in advanced industrialized societies, leading to structural changes in members of the Organization for Economic Cooperation and Development (OECD), which are globally switching from manufacturing to service industry. The growth of KIBS over the past 30 years has been attributed to the following factors. First, the KIBS sector, like the manufacturing industry, has gradually become the forefront of competition in the industries, as KIBS enterprises have shown higher and more persistent growth rates than less knowledge-intensive enterprises (Giotopoulos, 2014). Second, the requirement for knowledge-oriented services increases as the knowledge economy globalizes, and KIBS are recognized as improvers of regional economic growth in different advanced economies (Gallego & Maroto, 2015). Enterprises cannot rely on acquiring markets, technology or management information from the world through non-knowledge-oriented services. Third, changes in the intent of production have increased the available information about services and products. In particular, the need for new, improved, high-tech and innovative products rises with increasing income. The western world economy has encountered competition from developing countries, due to their lower costs, partially resulting from lower environmental standards (Panayotou, 2016). Therefore, industries and government have emphasized the importance of innovation and of promoting product quality.

Many studies have focused on KIBS since the late 1990s (Hu, Lin, & Chang, 2013; Muller & Zenker, 2001). Most of those studies explored the status and dynamic development, as well as the competitive strategies of KIBS companies in the global economy. Moreover, the importance of knowledge and innovation in the modern economy has led researchers to investigate the roles and functions of KIBS in the innovative system since the mid-1990s (Hu et al., 2006; Hu et al., 2013; Illeris, 1991; Miles et al., 1995; Strambach, 2001; Muller & Zenker, 2001; Wood, 2002; Tether, 2005).

Some references have concluded that KIBS is competitive. Previous works on KIBS have focused mainly on industrial regions, development and comparison, or on contributions to innovative activities and economic organizations. Some previous studies have investigated the formation and relationships of KIBS in high-tech regions (Hu et al., 2006, 2013; Wang et al., 2007), but did not discuss how knowledge exchange occurred, or the role and function of KIBS in developmental process in different regions. Those investigations also did not describe how KIBS approach knowledge and profession, or how KIBS form and maintain core assets. To fill the present knowledge gap, this study focuses on innovative KIBS activities in the developmental process, and has the following objectives: (1) to understand the functions and mechanisms of knowledge intermediaries in different organizations and developmental processes using empirical research, and (2) to examine the types of knowledge exchange and factors affecting KIBS. In particular, this work produces a novel empirical analysis of KIBS by focusing on the links between KIBS, innovation and forms of knowledge, based on a recent survey of manufacturers.

## 2. Literature review

KIBS enterprises now form a strategic industry due to increasing global competition. Competitiveness relies mainly on the ability to learn and innovate, especially in countries with high labor costs, so that businesses develop unique competitive advantages (Porter, 1990), increasing demand for KIBS and development of new business technologies (Daniels & Bryson, 2002; Miles, 2005; Pilat & Wölfl, 2005). Such demand emphasizes the ability of a business to absorb and apply knowledge, as well as integrating and employing external knowledge (Cohen & Levinthal, 1994).

Moreover, the rising importance of learning and innovation helps KIBS businesses to become intermediaries. Previous research has found that KIBS businesses transfer information to clients and also become involved in the learning process with customers (Hsieh, Chen, Wang, & Hu, 2015; Strambach, 2008; Toivonen, 2004). KIBS businesses become knowledge intermediaries by identifying related knowledge different from the links. Metcalf and Miles (2000) thus concluded that KIBS businesses are the agents of innovation, because they can transfer knowledge and stimulate innovation. To analyze the role and function of KIBS as knowledge intermediaries, this study applies regional innovation systems<sup>1</sup> for further investigation (Cooke, Boekholt, & To'Dtling, 2000). This work theoretically and empirically analyzes the roles and mechanisms of knowledge intermediaries in different organizations and development processes, as well as the types of knowledge exchange, and factors affecting knowledge exchange.

## **2.1. The roles played by KIBS in different spatial scales**

### *2.1.1. KIBS and regional innovation systems*

KIBS are becoming increasingly significant in supporting technologies, the economy and societies in developed countries (Doloreux, Freel, & Shearmur, 2010). KIBS comprise various components, which provide the fundamental elements of knowledge-intensive inputs to public or private departments and organizations, including participation in various activities. Human capital is the key element of inputs, which enables other firms or organizations to apply employees' knowledge and KIBS technologies (Miles, 2008). Although KIBS are promoters, they are also innovators developing new combinations, services, manufacturing and delivery services based on knowledge (Camacho & Rodriguez, 2008; Toivonen, 2004). Consequently, KIBS enterprises support industrial innovation, becoming deliverers of internal innovative activities.

Many studies have analyzed the innovative activities of KIBS. However, no systematic view of empirical research is available. Most investigations concluded that location significantly affects innovation because this exhibits strong spatial clusters in areas that contain specialized resources for firms, enabling these to produce, innovate and compete. Research related to regional development and innovation has focused on the importance of regional input elements and business dynamics (Asheim & Gertler, 2005; Cooke, Heidenreich, & Braczyk, 2004; Doloreux, 2004; Wolfe, 2009; Wood, 2005). Some works emphasize the importance of location because of the tendency of interactive learning and stimulation of knowledge flow among participants, thus creating spatial externalities (Uyarra, 2010). Accordingly, the functions of a regional innovative system are determined by knowledge generation, application and transfer by organizations, as well as agreement and relationships among systems (Doloreux, 2004).

### *2.1.2. Roles played by KIBS in regional innovation systems*

According to Cooke et al. (2000), a regional innovation system comprises two subsystems. One subsystem consists of the businesses of the main industrial cluster, and their clients and suppliers in the region. The other subsystem comprises supportive functions and innovative supporting infrastructure, such as universities and research centers (Hamdouch & Moulaert, 2006). The characteristics of a regional innovation system depend on the intra- and inter-subsystem interactions and knowledge flow (Cooke, 2001). A KIBS department stimulates knowledge flow between subsystems in a regional innovation system. Therefore, KIBS businesses are intermediaries encouraging collaboration among participants in a regional innovation system via knowledge transfer (Hu et al., 2016).

A regional innovation system emphasizes the stimulation of innovative collaboration and the development of interactive networks among innovators. The proximity of participants and the environment is assumed to be the essential factor for knowledge generation and transfer as well as for innovation in the region (Asheim & Gertler, 2005; Doloreux et al., 2010; Wolfe & Gertler, 2004). The environment comprises three essential elements, namely financial ability, institutionalized learning and productive cultures (Cooke, Uranga, & Etxebarria, 1997). A regional innovation

system has four major participants, namely government, research institution, university and corporate. (Pino & Ortega, 2018). With the motivation of regions, the participants attract, generate and disseminate information by providing common cultural and social values, which are involved in the social interaction between different participants (Cooke et al., 2000; Crevoisier, 2004).

The role of KIBS firms as knowledge intermediaries varies depending on the definition of regional innovation systems. KIBS firms often play a small role in narrow regions of innovation systems, but provide knowledge obtained from businesses of non-core competency. Accordingly, knowledge exchange occurs during the sales process. In particular, KIBS firms form relationships and interactions with clients who require professional knowledge during innovative processes.

### *2.1.3. Properties of innovation systems and types of knowledge exchange in different innovation modes*

Innovation modes that dominate in a region affect the types of regional innovation systems (Asheim & Gertler, 2005; Aslesen & Isaksen, 2007b; Maskell & Kébir, 2006). Jensen, Johnson, Lorenz, and Lundvall (2007) discussed two innovation modes, science, technology and innovation (STI) and doing, using and interaction (DUI). STI emphasizes innovative activities oriented by scientific or analytical knowledge (Coenen & Asheim, 2006; Lorenz & Lundvall, 2006). Most STI innovative activities occur in the R&D departments of firms, universities and research institutes. Knowledge is obtained from formal and scientific examinations and tests. That is, these activities rely mainly on analytical knowledge (Arundel et al., 2007; Asheim & Coenen, 2005; Jensen et al., 2007; Lorenz & Valeyre, 2006).

Coding analytical knowledge is simple, but not free. Codified analytical knowledge can be easily applied in the world (Iyer, Singh, Salam, & D'Aubeterre, 2006). Analytical knowledge flow is available worldwide and involves research talents participating in innovative activities, thus expanding its geographic reach (Moodysson, 2008). Thus, KIBS in STI business clusters generally support STI firms with knowledge and information in non-core competency (Aslesen & Isaksen, 2007b). Conversely, the DUI mode describes the innovation process of a firm. The DUI innovation mode is mainly adopted for value-added product and manufacturing processes, whether dominated by synthetic or symbolic knowledge. Based on the experiences and competition while facing new issues or problems, firms generate the applied knowledge, then collaborate with their clients or suppliers (Jensen et al., 2007). The progressive influence of DUI mode also indicates its dependence on proximity. Synthetic knowledge flow occurs among buyers, producers and suppliers, as well as within firms and local industries. Therefore, KIBS potentially functions in DUI clusters by transferring experiential and analytical knowledge into applicable knowledge.

Group learning of KIBS and their clients typically requires a closer interaction than the transfer of pure information and standardized services (Toivonen, 2004). Spatial proximity was the essential factor for some types of knowledge transfer in the past. Nevertheless, recent investigations have indicated that firms and clusters require contact with cross-regional knowledge (i.e. knowledge from outside the clusters) to prevent negative closeness resulting from outdated technologies and diminishing markets (Bathelt, Malmberg, & Maskell, 2004; Gertler & Wolfe, 2005; Hussain, Abbas, Lei, Haider, & Akram, 2017; Kautonen & Tukhunen, 2008; Lin & Hu, 2017). Restated, KIBS enterprises may be the intermediaries between international and domestic levels in global smart business.

## **2.2. The types of knowledge flow of KIBS businesses and their clients**

### *2.2.1. The theory and evidence related to knowledge flow*

Knowledge exchange depends on the level of difficulty of knowledge transfer, interpretation and absorption (Cohen & Levinthal, 1994; Todorova & Durisin, 2007). All references mention tacit knowledge (TK) and codified knowledge (CK) as the critical factors affecting the knowledge exchange.

Individuals are influenced by TK, which usually contains related background information. Considering that TK is more difficult to share with clients than CK (Bell & Zaheer, 2007), while CK is easier to transfer through reports, publications and patents (Hypothesis 1), CK still needs to be combined with TK to be fully applied by clients. Most TK is owned by KIBS firms (Collins & Hitt, 2006; Fontes, 2005).

Therefore, an efficient exchange of knowledge with customers sometimes relies on TK. Such exchange may depend on CK, especially across long distances. Some cases require both CK and TK for knowledge transfer.<sup>2</sup> According to Nonaka and Takeuchi (1995), socialization results from the exchange of TK between KIBS businesses and their clients, as well as the formation of TK sharing groups. Conversely, the exchange of CK with clients is based on the formation of CK sharing groups. KIBS businesses exchange both CK and TK internally when they convert CK into TK. Conversely, knowledge exchange occurs externally when KIBS enterprises convert TK into CK. Firms obtain, integrate and reorganize resources, including all types of knowledge resources, to improve products and manufacturing processes.

Few studies have investigated how KIBS businesses benefit from knowledge exchange, whether TK or CK. Thus, the knowledge-based view (KBV) of businesses indicates that KIBS businesses protect their critical knowledge. However, KIBS can no longer protect critical knowledge once the knowledge is generated from client interaction. Some TK is difficult to exchange, so the reapplication of knowledge by clients and competitors is also difficult to achieve. Conversely, codifying TK helps publish the specialized technologies and disciplines of KIBS, through which potential clients can be reached, thus further encouraging knowledge exchange (Hypothesis 2). Incentives that maximize the benefits of CK and protect the valued TK affect the strategies for knowledge exchange of KIBS. These incentives relate to the strategies for knowledge exchange, affecting business opportunities in the future. Consequently, this study analyzes the types of knowledge that KIBS businesses exchange with their clients, and the factors that enhance or prevent knowledge exchange between KIBS and their clients.

An enterprise with KBV is particularly appropriate for analyzing the types of knowledge exchange between the KIBS enterprises and their clients. KBV indicates that the KIBS enterprises should strategically position themselves as unique, valuable and inimitable knowledge sources. According to this view, knowledge sources of KIBS enterprises dominate the types of knowledge exchange between the enterprises and clients (Barney, 1991; Barney & Clark, 2007; Spender & Grant, 1996). Additionally, the types of knowledge exchange also depend on knowledge assets of the firms, including the knowledge sources, knowledge generation, knowledge possessed by employees (Hypothesis 3), the variance of practical and technical knowledge that managers have, and the strength of the links between enterprises and clients.

### 2.2.2. *Types of knowledge exchange between KIBS enterprises and their clients*

Based on the investigation of consulting industries in the USA, Hansen, Nohria, and Tierney (1999) concluded that the KIBS enterprises generally depend on two types of knowledge exchange with clients. That work indicated that KIBS firms relying on codified strategies focused mainly on the exchange of CK with their clients. In contrast, enterprises relying on personalized strategies care about exchanging TK with clients. Additionally, some KIBS enterprises employ a mixed strategy, namely, an interaction with clients using both CK and TK simultaneously. Enterprises that use the mixed strategy regard CK as valuable only when combined with TK (Foray, 2006). Moreover, Wood (2002) stated that the KIBS enterprises normally benefit from codification of knowledge of production technology and business model, and thus further apply CK. The benefit from the application of advanced technology and knowledge codification of production technology thus raises the likelihood of innovation of advanced technologies and knowledge exchange (Hypothesis 4). The interaction between the KIBS enterprises and clients is mostly imperceptible and tacit. Jensen et al. (2007) from Denmark found that enterprises with both CK and TK can fairly easily develop a product and service innovation. They further investigated the types of knowledge exchange

between KIBS enterprises and clients. The factors studied included differences in the knowledge sources, knowledge generation, strength of connection with clients, knowledge possessed by clients and employees, and participant levels of practical and technical knowledge.

As for the differences in knowledge sources, studies have found that enterprises cannot generate sufficient knowledge to assist clients in solving problems, but instead need external knowledge sources and supplies (Cohen & Levinthal, 1990). KIBS enterprises play a vital role in knowledge generation, transfer and application between enterprises and industries (Antonelli, 1999; Miles et al., 1995; Simmie & Strambach, 2006). The knowledge application by KIBS firms in different sectors thus facilitate knowledge exchange via CK (Hypothesis 5). KIBS enterprises are also considered to be the core of interactive learning centers (Muller & Doloreux, 2009). A learning system involves informal knowledge exchange with clients, suppliers, competitors, universities and research institutes. Based on the view of trading costs, the rise of variance of the external knowledge sources will result in knowledge exchange between the KIBS enterprises and clients mainly via CK rather than TK.

In terms of knowledge generation, an investment in research and development typically considers the following issues. The investment helps produce new knowledge, integrate new and old knowledge, and improve services, production, marketing and delivery. Conversely, the investment helps enterprises absorb and apply new knowledge from other organizations (Todorova & Durisin, 2007). New knowledge that is already delivered to the participants is more difficult to codify than well-established and complete CK (Contractor & Ra, 2002; Kogut & Zander, 1993). This finding shows that KIBS enterprises that perform R&D exchange knowledge with clients through TK rather than CK. The strength of connection is discussed in the following. Based on the investigation of social networks, the strength of connection influences the types of knowledge exchange among participants (Powell, Koput, & Smith-Doerr, 1996). Strong connections produce a consensus between the participants, thus further encouraging the exchange of TK. This investigation analyzes whether strong connections between KIBS enterprises and their clients lead to the exchange of TK rather than CK (Hypothesis 6).

The fourth factor is the level of customer knowledge. The KIBS enterprises can easily have a consensus on applied knowledge with the valued clients, resulting in a further promotion of knowledge exchange through TK, supplementary to CK. The similarity of cognition between KIBS enterprises and their clients also affects knowledge exchange through face-to-face interactions (Contractor, Wasserman, & Faust, 2006). The accumulation of past experiences of knowledge exchange with valued clients also helps exchange TK, since the clients can fairly easily obtain TK and fill the gaps in the CK (Simonin, 1999). Moreover, KIBS enterprises and their valued clients are familiar with each other's profession and characteristics. Thus, CK is supplemented by the exchange of TK.

The knowledge owned by employees provides KIBS enterprises with project-oriented services for specialized clients (Koschatzky & Stahlecker, 2006). The project-oriented and customized services satisfy the specific requirements of clients. KIBS enterprises rely on the specialized and localized knowledge of their internal talents to accomplish their unique and customized plans. To simultaneously generate employment and clients' knowledge, KIBS enterprises also need face-to-face interactions with clients (Crisuolo, Salter, & Sheehan, 2007; Miles, 2008). Therefore, personal exchange of accumulated knowledge improves the exchange of TK rather than CK.

The final factor discussed is the practical and technical knowledge of the participants. KIBS enterprises rely on specialized and unique knowledge collected by the employees providing services. Conversely, the ability of employees to perform projects depends on the capability to convert what they learn from the project into organizational skills (Davies & Hobday, 2005). The KIBS enterprises are oriented by their clients' projects, and learn from one project to another (Prencipe & Tell, 2001). In small- and medium-sized businesses, such learning

comprises complex issues that they cannot control by themselves (Criscuolo et al., 2007). To minimize the problems, and further improve the ability to transform what has been learned into organizational skills, KIBS enterprises are encouraged and driven to invest in knowledge management and technical improvement, thus increasing corporate absorptive capacity (Ashok, Narula, & Martinez-Noya, 2016). The resulting increased knowledge management capability can manage external knowledge better and integrate it into the internal knowledge (Ferraris, Santoro, & Dezi, 2017), and to increase knowledge acquisition and sharing among clients and themselves (Foray & Gault, 2003). Thus, given the higher financial capacity of larger firms, inter-corporate learning of CK is expected to be easier in larger-scale KIBS enterprises will be (Hypothesis 7), and the increased possibility of CK as the main type of knowledge exchange also is also likely to raise the variation of knowledge to be managed (Hypothesis 8).

### 3. Research design

This study analyzes the roles and functions of knowledge intermediaries, types of knowledge exchange and the factors that affect it in different organizations and developmental processes. An empirical investigation of KIBS was performed from a recent survey of manufacturers and analysis of multinomial logistic regression by SPSS.

#### 3.1. Data collection

The source of data for this work was *The Third Industrial Innovation Survey in Taiwan Area* (Wu, 2013) (see Appendix I for details), which was a survey of various industries in Taiwan, including manufacturing and service industry, examining the innovative activities of more than 10,000 manufacturers. This investigation targets the professional, scientific and technical services (M), namely service industries related to science and technologies, and the supportive services (N), namely service industries supporting business operations and some family activities (Directorate General of Budget, Accounting and Statistics, Executive Yuan, 2011). This investigation selected 390 manufacturers. The study analyzed the two classes of service industries (M & N), and further examined the types of knowledge exchange between the two service industries and their clients.

#### 3.2. Variables and hypotheses

This investigation derived from *The Third Industrial Innovation Survey in Taiwan Area* (Wu, 2013) the dependent variables that promote knowledge exchange involving CK, TK and MK (mixed knowledge). The nine independent variables were (1) percentage of R&D costs over (2) total revenue; (3) sum of advanced technologies applied by manufacturers; (4) numbers of employees; (5) percentage of knowledge workers over the total numbers of the employee; (6) source of the required knowledge; (7) use of patents; (8) the strength of links, and (9) business size and knowledge management. The dependent variables belonging to binary variables, and groups containing more than three categories, resulted in the selection of multinomial logistic regression, as well as analysis by descriptive statistics. Therefore, this study explored the relationship of types of the knowledge exchange occurring between KIBS and their clients with the critical factors affecting industrial development.

This study utilized a quantitative regression analysis with eight hypotheses, which were further verified based on the references related to types of knowledge exchange between the KIBS businesses and their clients.

Hypothesis 1. The possibility of CK as the main type of knowledge exchange with clients rises with increasing numbers of patents applied by KIBS enterprises.

Hypothesis 2. Knowledge exchange occurs through TK when KIBS firms promote technologies and innovation.



Hypothesis 3. Knowledge exchange mainly occurs through CK when KIBS firms hire more knowledge workers.

Hypothesis 4. The possibility of knowledge exchange through CK rises with increasing likelihood of KIBS businesses applying advanced technologies.

Hypothesis 5. KIBS firms that apply more knowledge have greater knowledge exchange through CK.

Hypothesis 6. KIBS firms that have stronger links with their clients are more likely to have TK as the main type of knowledge exchange.

Hypothesis 7. The possibility of CK as the major type of knowledge exchange with clients rises with increasing KIBS business size.

Hypothesis 8. The possibility of CK as the main type of knowledge exchange rises with increasing variation of knowledge management by KIBS businesses.

## 4. Results

### 4.1. Conversion of variables and description

This study is based on data from *The Third Industrial Innovation Survey in Taiwan Area* in 2011.<sup>3</sup> The dependent variables are the types of knowledge exchange between KIBS firms and their clients. Previous research has found that KIBS firms mainly rely on two different strategies for knowledge exchange. Businesses that rely on codified strategies generally exchange CK, while businesses that mainly exchange TK depend on personalized strategies (Hansen et al., 1999; Hsieh et al., 2015). Landry, Amara, and Doloreux (2012) found that some KIBS firms adopt a mixed strategy, interacting with clients through both CK and TK. Interaction using the mixed strategy often results from knowledge exchange with clients in different environment and background (Hsieh et al., 2014; Lee, Hu, Chang, Chia, & Lo, 2012). Therefore, this study refers to the types of knowledge exchange described above and categorizes interactions between KIBS and their clients into three types, namely CK, TK and MK exchange. The three different types of knowledge exchange are the dependent variables. Table 1 shows the description and definition of other variables employed in the research.

### 4.2. The analysis and results

#### 4.2.1. Analysis of basic characteristics

Table 1 shows the variables and types of industries used for descriptive statistics in this work. Analytical results reveal that the proportion of MK was highest (42.3%), followed by CK (38.5%) and TK (19.2%). These results indicate that the majority of KIBS firms of Taiwan (80.8%) studied during 2007 to 2010 in this research interacted with their clients mainly through MK and CK, confirming the ubiquitous practical difficulties of adopting TK, which is not easily codified, and is nuanced, making it hard to articulate (Ranucci & Souder, 2015). The dependent variables were as follows. The average and maximum numbers of employees of small- and medium-sized enterprises in Taiwan were 140 and 3,579, respectively.<sup>4</sup> The average and maximum percentages of costs of innovative technologies over the total revenue for small- and medium-sized enterprises were 8.8% and 55%, respectively. The average proportion of knowledge workers to the total number of employees was 18.6%, and the highest percentage was 80%.

The average of firms applying advanced technologies and fulfilling knowledge management were 1.5 and 0.8, respectively. The result of the connection with clients was high, at 72.6%. These findings indicate that the KIBS business consider both market (79%) and information (61%)

**Table 1. The analysis of basic characteristics**

<b>Dependent Variables</b>	<b>Description: the technology innovation for the enterprise during 2007 to 2010.</b>			<b>Number(%)</b>
Types of knowledge exchange with clients	- Codified knowledge as the major type			150(38.5)
	- Tacit knowledge as the major type			75(19.2)
	- Mixed knowledge as the major type			165(42.3)
Independent variables	Minimum	Maximum	Average	Standard deviation
Continuous variables				
-Numbers of employee	1	3579	141.0	394.9
-Percentage of technology innovation over the revenue	0	55	8.8	16.4
-Percentage of knowledge workers over the total numbers of employee	1	80	18.6	10.6
-Usage of advanced technology	0	8	1.52	2.4
-Application of knowledge management	0	6	0.8	1.5
Class variables		N		%
-Strength of connection with clients		107		27.4
Strong connection		283		72.6
Weak connection				
-Strength of knowledge sources				
Market sources (strong/weak)		308/82		79.0/21.0
Research sources (strong/weak)		62/328		15.9/84.1
Information sources (strong/weak)		239/151		61.3/38.7
-Patent		197		50.5
Yes		193		49.5
No				
-Size of enterprises <sup>a</sup>		311		79.7
Small		79		20.3
Large				
Industry category (Industry category code)				
Legal and Accounting Activities (69)		24		6.2
Activities of Head Offices; Management Consultancy Activities (70)		12		3.1
Architecture and Engineering Activities; Technical Testing and Analysis (71)		87		22.3
Advertising and Market Research (73)		43		11.0
Specialized Design Activities (74)		19		4.9
Other Professional, Scientific and Technical Activities (76)		22		5.6
Rental and Leasing Activities (77)		72		18.5
Employment Activities (78)		16		4.1
Travel agency (79)		18		4.6
Security and Investigation Activities (80)		17		4.4
Services to Buildings and Landscape Activities (81)		31		7.9
Business and Office Support Activities (82)		29		7.4

a: According to the standards established by Small and Medium Enterprise Administration, Ministry of Economic Affairs (2011), enterprises with no more than 100 employees are defined as small and medium-sized enterprises.

sources to be significant. However, only 15.9% of KIBS businesses considered sources of research knowledge as essential, indicating that these sources are fairly unimportant to the firms.

The proportions of businesses that had applied and had never applied for patents were similar. The KIBS businesses applied for fewer patents than the high-tech industry. Nevertheless, KIBS businesses are paying increasing attention to patent applications. The industries applying for patents were mainly architectural and engineering services, technical analysis and analytical services (22.3%), followed by the leasing industry (18.5%). This study still focused on small and medium enterprises. Whether the size of KIBS enterprises influences the types of knowledge exchange with clients is discussed below.

#### 4.2.2. *The overall analysis for service industry*

The types of knowledge exchange for the selected 390 businesses were first analyzed. The results reveal that 38.5%, 19.2% and 42.3% of the businesses exchange knowledge was based on CK, TK and MK, respectively. Two sets of regression equations were undertaken for knowledge exchange involving the three types of knowledge, using CK as the reference category.<sup>5</sup> Table 2 shows the analysis of how TK and MK affect the variables, based on the selected reference category.

- (A) The connection with clients was significant ( $\beta = -0.742$ ,  $p = 0.035$ ) for knowledge exchange mainly based on TK. The negative  $\beta$  value indicates that knowledge exchange using TK made fewer connection with clients than that using CK. Restated, the firms with knowledge exchange based on TK focus mainly on face-to-face interaction and spatial proximity, as indicated from previous studies (Hsieh et al., 2015; Jensen et al., 2007; Strambach, 2008).
- (B) Both the numbers of firms using advanced technologies ( $\beta = -0.214$ ,  $p = 0.003$ ) and using knowledge management ( $\beta = 0.302$ ,  $p = 0.009$ ) were significant for the knowledge exchanges through MK. The negative  $\beta$  value demonstrates that firms that exchanged MK insufficiently used advanced technologies, in contrast with CK. Additionally, the positive  $\beta$  value indicates that firms exchanging MK with clients are more concerned about knowledge management than firms exchanging CK.

#### 4.2.3. *The professional, scientific and technical services industry*

Among all the 390 selected enterprises in this investigation, 207 businesses belonged to the professional, scientific or technical services industries. The CK was again chosen as the reference category.<sup>6</sup> Table 3 lists the variables affected by the other two types of knowledge exchange, namely TK and MK.

- (A) The link with clients was significant ( $\beta = -0.980$ ,  $p = 0.05$ ) when knowledge exchange occurred through TK. However, the negative  $\beta$  value indicates a lack of connection with clients for the businesses exchanging knowledge through TK compared to the reference category CK.
- (B) The proportion of knowledge workers was significant ( $\beta = -0.012$ ,  $p = 0.034$ ) for the firms exchanging MK with clients. The negative  $\beta$  value shows that firms exchanging MK had a lower proportion of knowledge workers than the reference category. Conversely, the negative  $\beta$  value for the usage of advanced technologies ( $\beta = -0.205$ ,  $p = 0.019$ ) in MK group also indicates lower usage of advanced technologies than in the reference group. The  $\beta$  value of knowledge management is positive and significant, revealing that firms that exchange MK with their clients care more than firms that exchange CK about knowledge management.

#### 4.2.4. *Supportive industry*

Among the 390 enterprises selected in this investigation, 183 belonged to the supportive industry. The reference category was again selected as CK.<sup>7</sup> Table 4 shows the analysis of variables affected by the remaining two types of knowledge exchange, TK and MK.

**Table 2. The analysis of service industry using multinomial logistic regression (choosing codified knowledge as the reference category)**

	Types of knowledge exchange with clients			
	Tacit knowledge		Mixed knowledge	
	$\beta$	EXP $\beta$	$\beta$	EXP $\beta$
Numbers of employee	.001	1.001	.001	1.002
Percentage of knowledge workers over the total numbers of employee	-.005	.995	-.003	.997
Percentage of technology innovation over the revenue	-.009	.991	.003	1.003
Usage of advanced technology	-.084	.919	<b>-.214**</b>	.807
Application of knowledge management	.143	1.154	<b>.302**</b>	1.353
Strength of connection with clients	<b>-.742**</b>	2.101	-.363	1.438
Strength of knowledge sources				
-Market sources	.280	.755	.158	.854
-Research sources	-.782	2.185	.028	.973
-Information sources	.438	.646	.207	.813
Patent applied	.025	0.976	-.402	1.495
Small and medium-sized enterprises	-.605	.546	-.170	.844
$\chi^2(df)$	25.46(24)			
Nagelkerke R <sup>2</sup>	0.073			

Note: \*means the significance,  $p < .10$ ; \*\*means  $p < .05$  Data sources: this study.

**Table 3. The analysis of professional, scientific, and technical services using multinomial logistic regression (choosing codified knowledge as the reference category)**

	Types of knowledge exchange with clients			
	Tacit knowledge		Mixed knowledge	
	$\beta$	EXP $\beta$	$\beta$	EXP $\beta$
Numbers of employee	.001	1.001	.001	1.001
Percentage of knowledge workers over the total numbers of employee	-.008	.992	<b>-.012**</b>	<b>.988</b>
Percentage of technology innovation over the revenue	-.012	.988	.002	1.002
Usage of advanced technology	-.012	.988	<b>-.205**</b>	<b>.828</b>
Application of knowledge management	.075	1.078	<b>.383**</b>	<b>1.467</b>
Strength of connection with clients	<b>-.980*</b>	<b>1.802</b>	-.443	1.557
Strength of knowledge sources				
-Market sources	.637	.529	-.022	1.023
-Research sources	-.751	2.119	-.126	1.134
-Information sources	.126	.881	.227	.797
Patent applied	.147	.863	.169	.845
Small and medium-sized enterprises	-.497	.609	-.225	.799
$\chi^2(df)$	21.27(24)			
Nagelkerke R <sup>2</sup>	0.113			

Note: \*means the significance,  $p < .10$ ; \*\*means  $p < .05$  Data sources: this study.

**Table 4. Analysis of supportive industry using multinomial logistic regression (choosing codified knowledge as the reference category)**

	Types of knowledge exchange with clients			
	Tacit knowledge		Mixed knowledge	
	B	EXPβ	β	EXPβ
Numbers of employee	.001	1.002	.001	1.002
Percentage of knowledge workers over the total numbers of employee	-.002	.998	.004	1.004
Percentage of technology innovation over the revenue	.015	1.015	.029	1.029
Usage of advanced technology	<b>-.333**</b>	<b>.717</b>	<b>-.293**</b>	<b>.746</b>
Application of knowledge management	.396	1.485	.280	.1323
Strength of connection with clients	-.588	1.801	-.356	1.427
Strength of knowledge sources				
-Market sources	.189	.828	.180	.835
-Research sources	-.337	1.401	.465	.628
-Information sources	<b>.899**</b>	<b>.407</b>	.151	.860
Patent applied	-.238	1.268	<b>-1.013**</b>	<b>2.754</b>
Small and medium-sized enterprises	-.585	.557	.088	1.093
$\chi^2(df)$	21.27(24)			
Nagelkerke R <sup>2</sup>	0.113			

Note: \*means the significance,  $p < .10$ ; \*\*means  $p < .05$  Data sources: this study.

- (A) Based on the reference category, analytical results reveal that the usage of advanced technologies and sources of information ( $\beta = -0.333$ ,  $p = 0.026$ ;  $\beta = 0.899$ ,  $p = 0.027$ ) were significant for businesses that mainly exchanged knowledge through TK. Compared with the reference category, the negative  $\beta$  value indicates that the KIBS firms belonging to the support industry focus on sources of information rather than the usage of advanced technologies.
- (B) Both the usage of advanced technologies and the numbers of patents applied were significant for the KIBS enterprises using MK as the major knowledge exchange method. Nevertheless, the negative  $\beta$  value for both variables reveals that these enterprises were less concerned about either of the two factors than those in the reference category.

#### 4.2.5. Summary

These empirical results indicate that the KIBS enterprises focus on different factors based on types of knowledge exchange with their clients. The results are summarized as follows based on the type of knowledge exchange.

##### (A) Mixed Knowledge (MK)

KIBS enterprises exchanging knowledge with clients mainly based on MK emphasize collaboration, interaction and invisible knowledge exchange. Therefore, the enterprises focus on meetings, job rotation and internal incentive plans, and further promote exchange of knowledge and information between employees. The professional, scientific, and technical services industry (M) cares more about knowledge management than does the support industry (N). This is possibly because the professional, scientific and technical services industry requires more professional knowledge and knowledge management, because knowledge management is an increasingly accepted factor that facilitates innovations needed and improves business performance of corporates (Del Giudice & Maggioni, 2014), while the support industry focuses on providing supportive

services. Accordingly, knowledge management is less important for the supportive industry than for the professional, scientific and technical services industries.

Furthermore, KIBS enterprises exchanging MK with clients emphasize the research sources during the innovation process. Past studies have demonstrated that knowledge exchange for the KIBS enterprises and the clients occurs mainly through CK (McFadyen, Semadeni, and Cannella, 2009). Thus, the KIBS enterprises need many external knowledge sources for innovation. Firms in the support industry encounter various external knowledge sources, and focus on sources of information. Providing correct and helpful information enhances the trust and interaction between these firms and their clients.

#### (B) Tacit Knowledge (TK)

As TK emphasizes invisible flow and interaction, enterprises and clients interact silently. Nonetheless, the significant negative correlation shows that the KIBS enterprises are weaker in terms of interaction with clients and research sources for all types of knowledge exchange. Moreover, knowledge sources for the KIBS enterprises mainly exchange TK, demonstrating that research sources are less important than market and information sources. The reason is that KIBS firms interact less with research institutes than with high-tech enterprises. Additionally, the KIBS enterprises provide knowledge for their customers, which are mainly high-tech enterprises or organizations, rather than research institutes.

#### (C) Codified Knowledge (CK)

The KIBS enterprises that apply CK are often involved with advanced technologies. The KIBS enterprises need to convert in advance the knowledge that they provide to their clients into specialized capability. Thus, the KIBS firms achieve self-improvement by applying advanced technologies. Foray and Gault (2003) revealed that the input of resources to clients or enterprises improves the ability to share and obtain knowledge. Further research reveals that enterprises belonging to the professional, scientific and technical services industry care most about hiring knowledge workers, because they need professionals to participate and assist when providing services and exchanging knowledge with clients.

### 5. Hypothesis verification and discussion

This study analyzes the level of knowledge exchange between the KIBS enterprises and their clients in Taiwan, and the critical factors that affect it. Factors that promote and prevent knowledge exchange are, therefore, examined. Analytical results indicate that 19.2%, 38.5%, and 42.3% of KIBS enterprises exchange knowledge with clients mainly by TK, CK and MK, respectively. Most KIBS enterprises tend to exchange using MK or CK. The findings are the same as those of Foray (2006) and Jensen et al. (2007), that CK is useful only if it is adopted alongside TK.

Interactions between the KIBS enterprises and their clients are classified into three different types. Table 5 shows the analytical results of the hypotheses, revealing that only hypothesis 4 is valid for the service industry. Namely, the possibility of knowledge exchange through CK increases with increasing probability of the KIBS businesses applying advanced technologies. The hypothesis is also valid for the professional, scientific and technical services industry, and for the support industry. Individual examination for the professional, scientific, and technical services industry and the supportive industry are described as follows.

Hypothesis 1: the numbers of patents applied for by KIBS enterprises

Hypothesis 1 is only valid for the support industry. Firms in the entire services industry, and in the professional, scientific, and technical services industry, are more likely to use CK if they apply for more patents. Conversely, the supportive industry, while using CK for interactions with clients (e.g., reports, publications, patent documents), has recently increased focus on applying for patents.

**Table 5. Hypothesis testing**

	Service industry	The professional, scientific, and technical services industry	Supportive industry
Hypothesis 1	Invalid	Invalid	<b>Valid</b>
Hypothesis 2	Invalid	Invalid	Invalid
Hypothesis 3	Invalid	<b>Valid</b>	Invalid
Hypothesis 4	<b>Valid</b>	<b>Valid</b>	<b>Valid</b>
Hypothesis 5	Invalid	Invalid	Invalid
Hypothesis 6	Invalid	Invalid	Invalid
Hypothesis 7	Invalid	Invalid	<b>Valid</b>
Hypothesis 8	Invalid	Invalid	Invalid

Sources: this study

#### Hypothesis 2: technology and research innovation

In general, KIBS enterprises in that invest more in developing technologies generate more new knowledge, enabling them to receive innovative knowledge when providing services for clients. However, as the uncertainty of new knowledge makes it hard to codify, this work assumes that the KIBS enterprises interact with clients via TK. Furthermore, the assumption also includes the increasing costs of technology innovation. Nonetheless, the hypothesis is invalid, as firms with technology innovation tend to exchange knowledge through MK and CK.

#### Hypothesis 3: the ratio of knowledge workers

KIBS enterprises provide specialized and customized services to their clients through face-to-face interaction, especially the participation and assistance of knowledge workers during the exchanging process of CK. Therefore, this work assumes that the increased ratio of knowledge workers for the KIBS enterprises implies a requirement for knowledge exchange through CK rather than TK. This assumption is invalid for the entire services industry, but is valid for the professional, scientific and technical services industry. We deduce that the rise in knowledge workers of enterprises during provision of professional services and knowledge exchange simultaneously results in an increase in number of workers with TK. Accordingly, increased exchange of TK encourages the exchange of MK.

#### Hypothesis 4: the application of advanced technologies

Previous works indicated that KIBS enterprises prefer personalized strategies because of the promotion of diversity of advanced technologies and related connections, and the decrease in sources of research information, knowledge management diversity and business age. Knowledge exchange is thus mainly through TK. Analytical results of this study show that knowledge exchange through CK rises with rising usage of advanced technologies. Thus, KIBS enterprises care about knowledge management and the use of advanced technologies to improve employees' capability and organizational skills during the exchange process.

#### Hypothesis 5: different sources of knowledge

KIBS enterprises depend on external knowledge sources to solve problems for clients, irrespective of the size of enterprise (Cohen & Levinthal, 1990). A previous investigation found that the KIBS enterprises are centers for interactive learning with clients, suppliers, competitors and research institutes (Muller & Doloreux, 2009). However, exchange of TK through external knowledge sources has higher time costs lower knowledge absorbance than the exchange of CK

(McFadyen, Semandeni & Cannella, 2009). Consequently, this study hypothesizes that types of knowledge sources, in which the KIBS enterprises require during the innovation process, are mainly based on CK rather than TK. The invalidation of the hypothesis implies that increasing diversity of research sources encourages the exchange of MK. Conversely, KIBS enterprises rely more on research sources than on market information to fulfill the requirement of clients for CK.

#### Hypothesis 6: the strength of connections with clients

Invalidation of hypothesis 6 indicates that a rise in connections between the KIBS enterprises and clients does not raise the probability of knowledge exchange based on TK. Related references indicate that close interactions between KIBS enterprises and clients result in the exchange of TK (Hsieh et al., 2015; Powell et al., 1996). However, exchange of TK only occurs based on trust. Information exchange between businesses without trust makes exchange of TK difficult. Therefore, building trust between firms and clients is currently an important issue, as it further promotes TK exchange.

#### Hypothesis 7: the type of knowledge exchange and the size of KIBS enterprises

Hypothesis 7 is invalid for both the entire services industry and the professional, scientific and technical services industry, but is valid for the support industry. The businesses in this study are mostly small- and medium-sized and scattered, and, therefore, do not have the benefits of knowledge spillovers and interactions with large-sized enterprises. Additionally, the small- and medium-sized businesses, which cannot afford professional services, mainly rely on the supportive industry with CK.

#### Hypothesis 8: knowledge management

KIBS enterprises rely on both the specialized knowledge of employees and the ability to transform and convert knowledge while providing services (Crisuolo et al., 2007; Davies & Hobday, 2005). Consequently, enterprises need to invest in knowledge management and advanced technologies to improve employees' organizational skills. Hypothesis 8 is invalidated because the KIBS enterprises focus on exchanging via MK rather than via CK when knowledge diversity increases.

## 6. Conclusions

The hypotheses and the empirical results of this investigation describe the types of knowledge exchange between Taiwanese KIBS enterprises and their clients, as well as the critical factors that affect the exchange process. Although the empirical results do not agree with some references (Landry et al., 2012), they reveal the differences of industrial development leading to different types of knowledge exchange. According to the investigation and hypothesis verification, the results of types of knowledge exchange indicate that firms that mainly rely on the exchange of CK have an enhanced connection with clients, technologies, research innovation and the use of advanced technologies. Conversely, enterprises that exchange TK emphasize information sources during the innovation process, since it influences the type of knowledge exchange. The enterprises that mainly exchange MK focus on knowledge management and the information sources required during innovation processes, to minimize the issues and refine the capacity of knowledge conversion. Additionally, most small- and medium-sized Taiwanese KIBS enterprises have much smaller input of research innovation than large enterprises. Knowledge exchange in KIBS enterprises does not rely on TK. Instead, to protect valuable TK and build trust with clients, enterprises focus on face-to-face interactions, and apply CK supplemented by TK during the innovation processes (Hu, 2017). As Hsieh et al. (2015) mentioned, KIBS are initially based on STI industrial activities, and further closely resemble DUI industrial activities.

The managerial implication of this study is that central and local government can formulate special industrial policies and provide financial assistances for corporations to foster specific



desired industrial behavior. For example, the exchange of TK can facilitate the innovation of new item, while the exchange of CK and MK tends to facilitate mass production and sustain the operation of large corporates. In other words, firms that exchange TK, CK and MK need industrial policies tailor-made for them. For the theoretical implication, trust is a fundamental catalyst for the knowledge exchange of all kinds, enabling intangible benefits, such as an increase in quality of innovation or knowledge management, to be extraordinarily created during the exchange process. That is, the mutual benefits is beyond the content of contract.

This work analyzes types of knowledge exchange and the affecting factors, and provides suggestions for some applications and policies, but does not include estimates of competitiveness and value creation. Furthermore, due to the limit of the single period investigated, this study does not analyze the dynamic change during the specific period, or the influences of time changes. Overall, the Taiwanese KIBS enterprises tend to exchange knowledge with clients via mixed mode and CK, and fewer enterprises exchange knowledge through TK, as this is implicit and complex to communicate reciprocally. The enterprises emphasize different factors according to different types of knowledge exchange and services. Consequently, further investigation will examine the relationships among other variables and types of knowledge exchange between the KIBS enterprises and clients to gain a full understanding of the critical factors affecting knowledge exchange, and focus on strategies for transforming knowledge exchange and input into output and innovation. Finally, we hope that this study offers valuable and helpful experiences for KIBS in developing countries to facilitate the generation and diffusion of knowledge, and can complement the ability of public sectors in the developing economies, acting as agents of knowledge infrastructure.

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#### Notes

1. Regional innovation systems bring together private and public benefits, formal mechanisms, and other organizations. The functions of the systems are based on the relationships and agreements of the organizations, which can generate, apply and transfer knowledge (Doloreux, 2004). In other words, regional innovation systems comprise the innovative

knowledge and systems in regional industrial structures (Asheim & Coenen, 2005).

2. The concept of knowledge exchange is similar to that of socialization, externalization, combination, and internalization (SECI) (Nonaka & Takeuchi, 1995). Both concept emphasize integration of TK and CK.
3. Due to the second-hand information used in this study, the original data needed to be rearranged, transformed, reclassified or recoded before applying the data.
4. Manufacturing, construction and mining industries with paid-in capital below NT\$80,000,000 (US \$2,700,000) or industries with less than 200 employees, and other industries with paid-in capital below NT \$100,000,000 (US\$3,450,000) for the previous year or industries with fewer than 100 employees.
5. The analysis with maximum likelihood estimation under 95% confidence level indicates that the relationships between factors and variables are significant ( $-2 \text{ Log Likelihood} = 773.13$ ,  $\chi^2 = 25.46$ ,  $df = 24$ ). The variance of the dependent variables is 7.3%.
6. The analysis with maximum likelihood estimation under 95% confidence level indicates that the relationships between factors and variables are significant ( $-2 \text{ Log Likelihood} = 400.9$ ,  $\chi^2 = 21.3$ ,  $df = 24$ ). The variance of the dependent variables is 11.3%.
7. The analysis with maximum likelihood estimation under 95% confidence level indicates that the relationships between factors and variables are significant ( $-2 \text{ Log Likelihood} = 353.5$ ,  $\chi^2 = 21.6$ ,  $df = 24$ ). The variance of the dependent variables is 12.9%.

#### Correction

This article has been republished with minor changes. These changes do not impact the academic content of the article.

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<b>Appendix I. Description of the variables</b>			
<b>Variables</b>	<b>Variable Names</b>	<b>Description</b>	<b>Note</b>
Dependent variables (types of knowledge exchange with clients)	CK knowledge as the major type	Did your company ever engage in technology innovation for (1) research innovation in the company, (3) acquiring technologies related to equipment and software, or (4) acquiring exterior knowledge for the 14 <sup>th</sup> question in the survey, during 2007 to 2010?	Dependent variables are determined according to whether CK and TK are selected. The dependent variables are set as CK if more than two options for CK knowledge and no options for TK are chosen, and tacit if opposite conditions occur. The dependent variables are defined as mixed if options are selected for both CK and TK, with at least 2 options selected for one type.
	Tacit knowledge as the major type	Did your company ever engage in technology innovation for (2) authorizing other companies or research institutes or (5) training R&D personnel for the 14 <sup>th</sup> question in the survey, during 2007 to 2010?	
	Mixed knowledge as the major type	Did your company ever engage in technology innovation for (6) marketing activities for launching innovative products, (7) design activities for launching innovative products, or (8) other activities for preparation of innovation for the 14 <sup>th</sup> question in the survey during 2007 to 2010?	
Independent variables	Number of employees (sizes of enterprises)	The 36 <sup>th</sup> question in the survey: the number of employees in your company in Taiwan during 2007 to 2010.	(Number of employees in 2007 + the number of employees in 2010)/2 = average number of employees
	Percentage of knowledge workers over the total number of employees	The 37 <sup>th</sup> question in the survey: the percentage of employees with undergraduate degree or higher in Taiwan in 2010.	
	Percentage of technology innovation over the revenue	The 16 <sup>th</sup> question in the survey: percentage of cost of technology innovation over the total revenue in 2010.	
	Number of patents applied	The 24 <sup>th</sup> question in the survey: Has your company ever applied for a patent?	
	Sizes of enterprises	The 36 <sup>th</sup> question: the number of employees of your company in Taiwan during 2007 to 2010.	

(Continued)

<b>Appendix I. (Continued)</b>			
<b>Variables</b>	<b>Variable Names</b>	<b>Description</b>	<b>Note</b>
	Levels of advanced technology used	The 38 <sup>th</sup> question in the survey: does your company have the following skills? (1) Image design, composition, advertising; (2) design and services; (3) multimedia (integrating music, image, word, animation, photo); (4) web design; (5) software development; (6) market research; (7) engineering/applied science; (8) mathematics, statistics, database management	
	Numbers of application of knowledge management	The 39 <sup>th</sup> question in the survey: has your company ever used the following methods to stimulate employees' innovation or creativity between 2007 and 2010? (1) Brainstorming meetings; (2) forming cross-disciplinary or interdisciplinary teams; (3) job rotation for employees in different departments; (4) providing bonuses for employees proposing creative ideas; (5) offering rewards for employees proposing innovative ideas, such as additional free time, praise, or more interesting work; (6) providing innovation and creativity training for employees	
	Strength of connection with clients	In terms of (3) clients or consumers for question 21.1 in the survey, what is the most important partner that your company collaborates with?	
	Strength of knowledge sources	The 20 <sup>th</sup> question in the survey: the importance of knowledge sources for technology innovation during 2007 to 2010.	

(Continued)

**Appendix I. (Continued)**

Variables	Variable Names	Description	Note
	-Market sources	(1) suppliers of equipment, materials, services or software (2) clients or consumers (3) competitors or other companies (4) consultants, private laboratories or research institutes	The market source is weak if only one option is selected. The market source is strong if more than two options are selected.
	-Research Sources	(1) universities or other institutes for higher education (2) government or public research institutes (e.g., ITRI)	The research source is weak if only one option is selected. The research source is strong if more than two options are selected.
	-Information sources	(1) seminars and exhibitions (2) scientific or business journals or magazines (3) professional and industrial societies (4) institutes or documents regulating standards for technologies or services	The information source is weak if only one option is selected. The information source is strong if selecting more than two options are selected.

Sources: derived from The Third Industrial Innovation Survey in Taiwan Area (Wu, 2013).



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