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Abstract

This paper investigates the ability of knowledge intensive business firms (KIBS) to engage in co-innovation with client firms. Co-innovation relates to KIBS competitive advantage as knowledge creators and sources of innovation. We propose a resource-based model where knowledge-related resources and capabilities explain why certain KIBS firms are able to co-innovate. We explore the model on a sample of Dutch environmental investigation firms. Our exploratory results confirm the expected dominant role played by the learning capabilities of KIBS firms in explaining their ability to co-innovate.

Keywords: KIBS, co-innovation, resource-based, knowledge

1. Introduction

Knowledge intensive business services (KIBS) provide specialized knowledge to other sectors. Accordingly, KIBS function as an interface between their clients' knowledge base and the wider knowledge base of the economy. Thereby, KIBS shape the resource distribution among client firms and play an important role in the development and commercialization of new products, processes and services (Muller and Doloreux, 2009). In this light, KIBS are seen to function as catalysts in innovation systems (Muller and Zenker, 2001; Castellacci, 2008; Castaldi, 2009).

KIBS can act as sources of innovation for other firms, and through their strong relation with client firms, some KIBS act as co-producers of innovation (Den Hertog, 2000; Van Ark et al., 2003; Muller and Doloreux, 2009). Client firms with a deep commitment to innovation, a high absorptive capacity and large networking capabilities are more likely to use KIBS as specialized knowledge providers and engage in cooperative innovation (Tether and Tajar, 2008). Co-innovation is defined as innovation occurring at a client firm with inputs of both the client and KIBS firm, which would not have occurred without the support of the KIBS firm (Wood, 2004). In the typology proposed by Gallouj and Weinstein (1997), co-innovation corresponds to 'ad hoc innovation,' requiring changes in competences, technologies and an interactive construction of new outcomes (De Vries, 2006).

Previous studies have illustrated how KIBS and client firms are related to each other and the resources and capabilities a client firm needs in order to use external knowledge provided by KIBS (Muller and Zenker, 2001; Tether and Tajar, 2008). Thereby, the focus has largely been on identifying properties of client firms that explain their use of KIBS and much less on properties of KIBS firms which explain their ability to act as sources of innovation. Specifically, it remains unclear which resources and capabilities KIBS firms need in order to go beyond knowledge diffusion and to be able to engage in co-innovation projects with client firms. The focus on co-production of innovation is particularly meaningful for at least two reasons. First, given that the degree of innovativeness of KIBS firms is best assessed in terms of the extent of changes brought about within client firms (Muller and Doloreux, 2009), KIBS firms that are able to engage with client firms in co-innovation demonstrate a higher degree of innovativeness. Therefore, the positive role played by KIBS firms as knowledge brokers in innovation systems is enhanced by their ability to stimulate innovation in cooperation with client firms. Second, co-innovations are complex interactive processes where KIBS firms show and train their abilities. Co-innovations are then of strategic relevance for KIBS firms to enhance their competitive advantage as knowledge creators. In this paper, we argue that co-innovation projects require specific resources and capabilities from the KIBS firm. The main research question addressed in this study is therefore: *Which resources and capabilities of KIBS firms affect their ability to co-produce innovations with client firms?*

The present study applies a resource-based perspective to determine which resources and capabilities KIBS firms need in order to support innovations in and with client firms, thereby focusing on the service provider's side of the aforementioned KIBS – client relation. This is done by exploring an original conceptual model, relating KIBS firms' resources and capabilities to their ability to co-produce innovation using data on a specific sub-sector of KIBS, namely Dutch environmental investigation services (EIS). By focusing on a specific type of so-called technical KIBS (Miles et al., 1995), a rather homogeneous set of firms is selected, helping to reduce sectoral biases that may otherwise arise. Furthermore, in the light of the recent rise of stricter environmental policy the focus on the EIS sector also becomes increasingly relevant; EIS firms can serve to improve the environmental performance of new and existing companies through advice and innovation. Since EIS firms are strongly dependent on national regulations, this study focuses solely on Dutch firms in this sector. In addition, this research focus complies with the need for studies investigating specific KIBS categories (Ojanen et al., 2007). It also provides a quantitative analysis that complements existing qualitative studies on the determinants of co-innovation (Muller and Doloreux, 2009).

The following section discusses the theoretical framework and the conceptual model linking a KIBS firm's resources and capabilities to its ability to co-produce innovation. In Section 3, the concepts specified in the model are operationalized. Section 4 describes the data and statistical methods used in this study. The results obtained are discussed in Section 5. Conclusions drawn from this study that provide an answer to the main research question are presented in Section 6, together with a discussion of the research carried out.

2. **Theoretical framework**

2.1 The role of KIBS in the innovation system

In the classic view of service innovation, the service firm is supplier-dominated (Pavitt, 1984). This view, however, does not apply to KIBS (Miles et al., 2005). Evidence shows that KIBS firms are specialized suppliers of knowledge responsible for innovations within client firms. In a national economy, the core function of KIBS is twofold (Den Hertog, 2000; Castellacci, 2008):

- to develop fundamental and/or professional knowledge i.e. knowledge or expertise related to a specific (technical) discipline or (technical) function domain

- to supply intermediate products and services that are knowledge-based solutions, through specialized products, training and/or consulting

Via this core function, KIBS firms are able to influence the innovation processes of other firms in different sectors. This influence is exerted via various means such as providing an expert manager, a tailor-made software package or written advice (Den Hertog, 2000). As the services provided by KIBS firms are diverse, innovations developed by KIBS are equally heterogeneous (Freel, 2006). A rough distinction proposed in the literature is the one between technical and professional KIBS (Miles at al, 1995). More nuanced and empirically driven classifications suggest different degrees of innovation-orientation of KIBS firms (Freel, 2006; Corrocher et al., 2009). In fact, the most innovative KIBS firms retain the option of differentiating their roles across client firms. Within specific groups of KIBS firms, innovation can take various forms reflecting different strategies (Corrocher et al., 2009). Depending on the vision and strategy of its management, a KIBS firm can perform at least three different roles. First, KIBS can facilitate the innovation process by supporting client firms with innovations that originated at the client firm. Second, KIBS can act as carriers of innovation, influencing the innovation process of client firms by implementing innovations developed elsewhere. Finally, KIBS can be a source of innovation, initiating and developing the innovation process of client firms (Den Hertog, 2000). The focus of this study is on which resources determine whether or not KIBS firms perform this last role. Therefore, co-innovation is defined as an innovation occurring at a client firm with inputs of both the client and KIBS firm, that would not have happened without the support of the KIBS firm (Wood, 2004).

2.2 Ability of KIBS firms to co-innovate

Where differences in roles can be attributed to different strategies, the ability of KIBS firms to co-produce innovation is expected to depend on the firms' resources and capabilities. In this study, a service firm is perceived as a collection of resources and capabilities which is in line with the resource-based view of the firm (Wernerfelt, 1984) and the more recent capability-based view of the firm (Teece, Pisano and Shuen, 1997; Dosi, Nelson and Winter, 2000). Resources are seen as specific 'stocks' of tangible and intangible assets that are tied to a firm. Capabilities are process-oriented and emphasize the role of adapting, integrating and managing organisational assets, like resources, to gain a competitive advantage. A further specification of the relation between resources and capabilities is made within the knowledge-based view, by relating combinative capabilities to the creation of new knowledge (Kogut and Zander, 1992; Grant, 1996). A full-fledged knowledge-based view of KIBS firms has been proposed by Larsen (2001) and explored via case studies. Larsen views KIBS as 'distributed knowledge systems', where the knowledge embedded in employees and in their social relations shape organizational capabilities. Strambach (2008) has advanced the conceptual characterization of KIBS knowledge dynamics by mapping different types of knowledge used and produced by KIBS. Strambach (2008) summarizes three main properties of KIBS firms that relate to the key role of knowledge resources and learning capabilities.

First, knowledge is not only the production factor that KIBS use most intensively, it is also what they sell (Gallouj, 2002).

Second, selling knowledge to client firms requires complex and intense interaction with client firms where both parties engage in interactive learning (Den Hertog, 2000; Sundbo, 2001).

Third, the content of interactive learning relates to expert knowledge of the KIBS firms adapted to the needs of the client firms (Muller and Zenker, 2009).

These three properties assume an even greater meaning when considering instances of co-innovation rather than the standardized provision of services. Based on these properties, we expect two main mechanisms through which resources and capabilities explain the ability of KIBS firms to co-innovate. On the one hand, the possibility for the KIBS firm to provide knowledge that is complementary to the knowledge possessed by the client firms is directly related to its available knowledge base (Strambach, 2008). We view the knowledge base of a KIBS firm to be embodied in its expert employees, management and technologies, in other words, in its human, managerial and technological resources. On the other hand, better knowledge bases also increase the absorptive capacity of KIBS firms and in turn increase their ability to process and create new knowledge (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998). It follows that if a KIBS firm has a low level of absorptive capacity, it will not be able to adapt its knowledge to specific client firms and will in general, lack knowledge generation capabilities (Lane and Lubatkin, 1998; Zahra and George, 2002).

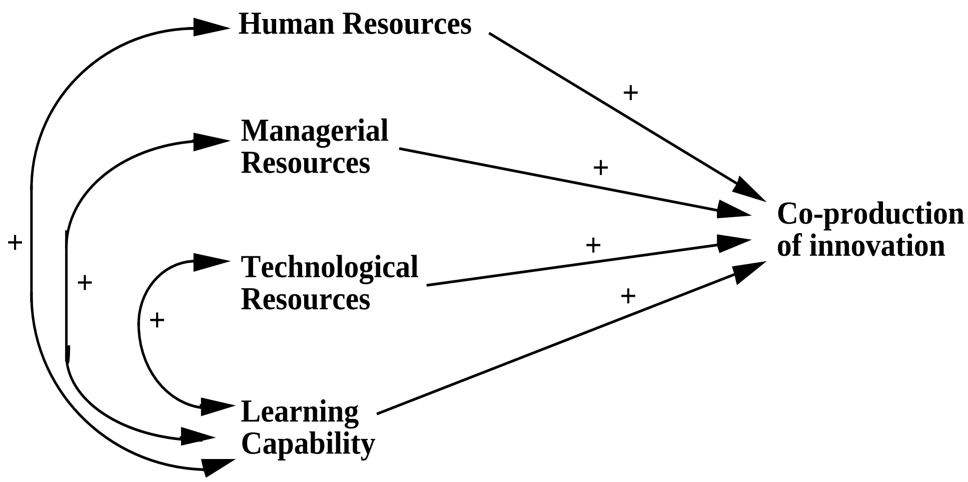
In sum, a better knowledge base as captured by a KIBS firm's resources is directly related to the quality and relevance of the knowledge transferred as a service. At the same time, a better knowledge base is indirectly related to the innovative potential of the KIBS firm since it enhances the firm's absorptive capacity and learning potential.

In projects where innovations are co-produced by a KIBS firm and a client firm, the need for complex interactions is high, and the resources and capabilities of the KIBS firm come under pressure. Therefore, the occurrence of co-innovations is highly suited to analyze the resources and capabilities required by KIBS firms to successfully engage in co-innovative projects with client firms.

It should be noted that by considering the ability to co-innovate, we implicitly assume that instances where co-innovation does not happen, put less pressure on KIBS firms regarding the quality of their resources and capabilities. For instance, in situations where KIBS firms only apply already available solutions to fulfill the client's contract, there is no co-innovation. Furthermore, if the innovation is developed by a KIBS firm before the project with the client firm begins, an 'off the shelf' service is sold by the KIBS firm and there is again no co-innovation (Tether and Tajar, 2008). Instead, the co-production of innovation requires a customized and fitting input from the KIBS firm. While firms can choose *not* to co-innovate as part of their strategy, it is expected that actual participation in co-innovation requires a KIBS firm to challenge its resources and capabilities at a higher level. Based on this assumption, we propose a model explaining the ability of KIBS firms to co-innovate as depicted in Figure 1 below.

We identify four categories of resources and capabilities. Human resources refer to the knowledge and skills embedded in the expert employees of KIBS firms, while managerial resources refer to the knowledge and skills of the managers involved. Technological resources relate to the expert and specialized knowledge possessed by the KIBS. Finally, learning capability is a multi-dimensional concept aimed at addressing the extent to which firms as a whole are able to process, combine and adapt existing knowledge. Figure 1 illustrates how the resources and learning capability are related to the co-production of innovation. The learning capability will covariate positively with the quality of human, managerial and technological resources available, because these resources are only partial constituent elements of the organizational learning process. This implies that the organizational learning capability r cannot be specified to represent the common variance of human, managerial and technological resources, or as an intermediate variable. Therefore, the knowledge embedded in experts, managers and technology is specified to be correlated with the learning ability of the KIBS firms. The relations with expected positive signs depicted in Figure 1 represent the hypotheses to be explored.

Figure 1: Conceptual model linking KIBS resources and capabilities and ability to co-produce innovation



3. Operationalization

This section discusses the operationalization of the concepts in the resource-based model, explaining the ability of KIBS firms to co-innovate. We discuss how each resource and capability is related to the ability of a KIBS firm to co-produce innovations with client firms, by illustrating how each concept can increase the likelihood of the occurrence of co-innovation by a KIBS firm. We discuss relevant empirical indicators for each concept (see Table 1).

3.1 Co-production of Innovation

The dependent concept is the “co-production of innovation,” denoting whether or not a KIBS firm is able to engage in complex interactions with a client firm aimed at realizing a co-innovation. The firms included in the sample were asked to consider their most representative innovation project undertaken in the last two years. In this way, the questionnaire remained neutral in referring to co-innovation, thereby preventing a bias in the responses. In all cases, desk research (consisting of follow-up calls and the analysis of company websites) was performed to check for the possible misidentification of the company's ability to produce co-innovations. Two dimensions are necessary to identify co-innovation: the location of the co-innovation and the degree of standardization.

In a co-innovation project, the location of the co-innovation should be at the client firm and the KIBS firm should function as the primary sender of knowledge. As part of the interactive learning process, the KIBS firm also receives knowledge, but only as feedback on the primary knowledge input. The degree of standardization is taken into account to ensure that 'off the shelf' services are not identified as part of co-innovation projects (Tether et al., 2001). The degree of standardization is measured by determining whether the innovation was designed to be in a standardized form and possibly customizable/adaptable to other environments (actors/markets) or whether it is specific for the project. The nature of services almost always leaves room for customization, so there are two possible indicator scores: designed as being standard and designed as being specific.

Only when the innovation is located at, and designed specifically for, the client firm, is the KIBS firm identified as being able to co-innovate. If the innovation is located at the KIBS firm, or if the innovation is not specific, the KIBS firm is not co-innovating.

3.2 Human resources

The quality of the human resources will be measured based on two indicators: the number of highly educated experts and the number of compulsory training courses per year for these expert employees. The first indicator is relevant, as the highly educated experts working for the KIBS firm form a significant part of the pool of available knowledge within the KIBS firm. The possibility for the KIBS firm to provide knowledge in co-innovation projects is directly related to these experts. The second indicator is related to the development of knowledge and skills through training courses. In technology-based KIBS the focus is on synthetic knowledge, which is used to provide product development services (Strambach, 2008). The underlying process of synthetic knowledge creation relies heavily on new combinations of existing knowledge and experience in learning by doing, using and interacting (Freel, 2005; Strambach, 2008). Mandatory training courses can therefore be seen as a method of KIBS firms to improve the knowledge base of expert employees which is of primary importance in co-innovation.

3.3 Managerial resources

Capable personnel can only get the job done if activities are sufficiently coordinated and supported by the management of the KIBS firm. Hansen and Wernerfelt (1989) argue that the management can influence the behavior of the other employees and thereby the performance of the organization by taking factors such as structure, planning and control into account. The management establishes an organizational 'climate', which can improve firm performance. The lack of supportive and competent management hampers the firm's ability to efficiently tap into its knowledge and skills pool, making it impossible for the firm to participate in co-innovation projects. The knowledge and skills of the management are therefore also important determinants of a KIBS firm's ability to co-innovate. The concept of "managerial resources" captures the quality of the management team's knowledge and skills. Specific to each firm, the "managerial resources" concept is defined as the available human-embodied knowledge and experience in the management team necessary to expertly perform the functions of administration, management, operations and planning (Hansen and Wernerfelt, 1989;

Hitt et al, 2001), indicated by the average educational level and age of the management team members as a proxy of their experience.

3.4 Technological resources

To successfully complete their tasks, technical KIBS firms depend on both hardware and software, such as measuring equipment or specialized software packages to utilize measurement results. A key characteristic of KIBS firms is that they provide expert knowledge. While part of this knowledge resides in the human resources of the firm, specialized hardware and software further allow the KIBS firm to provide clients with expert, firm specific, complementary knowledge (Gallouj and Weinstein, 1997, Den Hertog, 2000). This is further illustrated by the fact that much of the technological assets owned by firms do not enter the market, due to unwillingness to sell them or due to difficulties in their transaction (Teece, Pisano and Shuen, 1997). Therefore, a firm's technological assets are clearly differentiators among firms and can serve as (technology-embedded) knowledge pools and/or facilitators for the service process. An important innovation source for service firms is the investment in, and development of, specific hardware and software (Sirilli and Evangelista, 1998). We argue that those KIBS firms that are able to produce their own hardware and/or software are more likely to be successful co-innovators. The production of hardware and software allows the KIBS firms to adjust even further to the specific needs of the client, by altering existing technology assets or creating new ones. Technological resources can be inputs to as well as outcomes of the co-innovation process, thereby realizing one of the key conditions of ad hoc innovations (Gallouj and Weinstein, 1997).

In this study, the quality of a KIBS firm's technological resources is operationalized by the extent to which the KIBS firm is able to produce original hardware and software. These indicators are measured on a 5-point Likert scale, ranging from 'completely not applicable' to 'fully applicable'.

3.5 Learning capability

Besides the knowledge base itself, the ability of the firm to process and transform knowledge is essential to the functioning of a KIBS firm (Muller and Doloreux, 2009). As co-innovations rely on sharing and combining knowledge and skills, the learning capability of a KIBS firm is expected to be strongly related to its ability to co-innovate.

Organizations can learn from direct experience and experience of others by developing a conceptual framework to interpret that experience (Levitt and March, 1988, Muller and Doloreux, 2009). Diffusion of experience also plays an important role because company-level knowledge should be useable by every individual in the firm and therefore should flow through the firm (Levitt and March, 1988; Kogut and Zander, 1992, Prieto and Revilla, 2006). As argued earlier, the absorptive capacity of a KIBS firm is critically related to its learning capability (Cohen and Levinthal, 1990). By learning capability, we mean the ability of the individuals of a firm to efficiently store and manage both the internal knowledge pools and the external knowledge pools related to customers, and marketing and distribution (Guan and Ma, 2003; Prieto and Revilla, 2006). Tools and activities related to knowledge management have been found to stimulate innovation at the firm level (Darroch, 2005). They do that by reducing the costs of accessing knowledge already available in the organizations, as well as by allowing a better re-use of prior knowledge.

There are different ways to organize and store codified forms of knowledge. Lessons learned from past experiences are recorded in documents, accounts, files, operation procedures, rule books and more (Levitt and March, 1988). Knowledge codification is important for capacity building and as a second order learning process (Kogut and Zander, 1992). The creation of codified knowledge forces those involved in the creation process to draw explicit conclusions about the implications of experiences (Zollo and Winter, 2002) and de-contextualizes knowledge (Acha et al., 2005). Codification facilitates diffusion of existing knowledge as well as the coordination and implementation of complex activities (Zollo and Winter, 2002). This implies that the codification process is especially relevant for the co-production of innovations.

Four indicators are used to measure the learning capability of a KIBS firm: the presence of a knowledge manager, the presence of client and project evaluation databases, and the extent to which idea boxes are used. A knowledge manager helps in the formalization and structuring of the learning process of a KIBS firm. The databases are used to expand upon the internal knowledge pool, by taking into account the lessons learned from experience. Finally, idea boxes are used to utilize creativity available within a KIBS firm.

Table 1: Definitions, dimensions and indicators of model concepts

Concept	Dimension	Indicator	Scale of measurement
Co-production of innovation (COIN)	Location of innovation	Classification: service firm, client firm, other firm	Binary (COIN= 1 if location is client firm and degree is high)
	Degree of standardization	Classification: low degree/specific, high degree/standardized	
Human resources (HR)	Quality of human resources	Number of highly educated experts (HR1)	Ratio
		Number of compulsory training courses per year for experts (HR2)	Ratio
Managerial resources (MR)	Quality of managerial resources	Average education level of the management (MR1)	Ratio
		Average age of the management (MR2)	Ratio
Technological resources (TR)	Quality of technological resources	Extent to which the firm is able to produce original hardware (TR1)	Ordinal (5-point scale)
		Extent to which the firm is able to produce original software (TR2)	Ordinal (5-point scale)
Learning capability (LC)	Quality of learning capability	Presence of a dedicated knowledge manager within the firm (LC1)	Binary (1 = yes, 0 = no)
		Presence of a client database (LC2)	Binary (1 = yes, 0 = no)
		Presence of a project evaluation database (LC3)	Binary (1 = yes, 0 = no)
		Extent to which idea boxes are used by the firm (LC4)	Ordinal (5-point scale)

4. Methodology

This section discusses the data collection and the statistical methods that were used for a test of the hypotheses depicted in Figure 1 to answer the main research question.

4.1 Data collection

The indicators developed in the previous section were measured through the use of a questionnaire. The questionnaire was purposely designed to be as brief as possible, relating one question to each indicator. Because response rates are typically low, a short questionnaire was expected to encourage representatives of EIS firms to collaborate.

Via several internet search engines, the VVM member guide and the Dutch Chamber of Commerce, a list of Dutch EIS firms was composed. A company is considered to belong to the Environmental Investigation Services sector when it has a focus on services in (one of) the domains of air-, soil- and water quality, construction/facility quality measurements, vibration emissions and sound emissions, by providing a research and consultancy component. Firms were selected based on age; firms active in the sector for at least one year were included. Start-up firms were not selected, because they did not had the possibility to develop capabilities and networks necessary to act as co-innovators.

No publicly released statistics were available regarding the 'environmental investigation services', or comparable sub-sectors such as 'environmental management and consultancy'. However, searches with different Dutch online search engines produced around 500 hits for registered environmental consultancy firms in the Netherlands. After application of the selection criterion of domain of activity and firm age, the Dutch population of EIS firms addressed in this study comprised 200 firms. These firms were invited to complete the questionnaire[1]. Ultimately, 21 EIS firms returned a completed questionnaire resulting in a response rate of just above 10%. The sample contains some large firms and many medium-sized and small firms.

4.2 Data analysis

The dependent concept of co-innovation is directly measured as a dichotomous variable. All the independent concepts that were argued to have positive effects on the dependent concept are indicated by 2-4 observed variables. Therefore, the independent concepts will be specified as unobserved latent variables to be measured on their own specific set of observed indicators summarized in table 1. In fact, the values of every observed indicator in each set are specified to consist of a common value induced by the unobserved latent variable specified and a unique value of its (random) measurement error. The complete measurement model for all independent unobserved latent variables representing the independent concepts in figure 1, including their expected covariations, is specified in the computer program LISREL® (Jöreskog and Sörbom, 1993). For reasons of identification, the scale of measurement of each unobserved latent variable must be fixed by specifying one of the regression coefficients of its effects on the observed indicators a priori as equal to 1.0. Additionally, the observed dependent variable 'co-innovation' is specified in LISREL together with the regression coefficients of the effects of the independent unobserved latent variables and a

[1] A copy of the questionnaire (in Dutch) can be obtained from the authors.

(random) regression error. The advantage of LISREL is that all unknown constant parameters in this model, i.e. regression coefficients and (co)variances of the independent latent variables and the measurement and regression errors, are estimated simultaneously from the input correlation matrix *S* of all observed indicators summarized in the far right column in Table 1.

The observed indicators are measured on different scales of measurement, namely discrete (dichotomous and ordinal) and continuous (ratio) scales. To include in *S* minimum variance unbiased estimate of all individual correlations, the correlations among two discrete indicators, a discrete and a continuous indicator and two continuous indicators are estimated as polychoric (Olsson, 1979), polyserial (Olsson et al., 1982) and Pearson correlations (Wonnacott and Wonnacott, 1990), respectively, by means of the computer program PRELIS™ (Jöreskog and Sörbom, 1995). The resulting input correlation matrix *S* used for estimation of the LISREL model is presented in Appendix A. As S is not a positive definite matrix, the LISREL model is estimated by means of the Unweighted Least Squares method (e.g. Saris and Stronkhorst, 1984).

5. Results

5.1 Descriptive statistics

To gain some insight into the extent to which the EIS firms in the sample were involved in co-innovation and relied on their human, managerial and technological resources and (organizational) learning capability for doing so, the estimates of the means and standard deviations of the selected observed indicators (see table 1) are presented in Table 2.

Table 2 Descriptive statistics of the observed variables

	N	Mean	Std. Deviation
COIN	21	.4762	.499
HR1	21	199.0952	375.339
HR2	21	.9048	1.546
MR1	21	2.3810	0.732
MR2	21	43.0476	5.277
TR1	21	1.5714	0.4320
TR2	21	2.6667	0.667
LC1	21	.3333	0.471
LC2	21	.9048	0.293
LC3	21	.6190	0.382
LC4	21	2.2381	0.572

Only 10 of the 21 EIS firms in the sample were involved in co-innovation in the last two years (2007-2008). On average, the firms in the sample employed almost 200 experts directly involved in EIS who attended one compulsory training course per year. But the variations among the sample firms were considerable as indicated by coefficients of variation > 1 for HR1 and HR2 (e.g. Wonnacott and Wonnacott, 1990). The managers of these firms were on average 43 years old and were almost all educated at a poly-technical level. Furthermore, the technological resources of the EIS firms in the sample were not very well developed as indicated by the relative low mean values of TR1 and TR2. This applies especially to their capability to produce original hardware and to a lesser extent to their capability to produce original software. But there were considerable differences in these capabilities among the firms. Finally, most firms explicitly documented their clients and project evaluations. But they were rather weak in mobilizing internal knowledge sources and in appointing a dedicated knowledge manager responsible for diffusing and combining the acquired knowledge about clients, project evaluations and internal novel ideas within the firm.

To gain insight into differences among individual EIS firms regarding their human, managerial and technological resources and learning capability correspond with their differences in participation in co-innovation with client firms, the conceptual model in Figure 1 specified as a LISREL model has been statistically tested.

5.2 LISREL estimates

The LISREL estimates of the hypothesized correlations among human, managerial and technological resources and learning capability and their effects on co-innovation at the firm level as specified in the conceptual model (Figure 1) and the measurement model for the concepts of human, managerial and technological resources and learning capability are presented below in Figure 2 and Table 3. The significance of the estimates is indicated by their probability of not being different from zero (*ns*: $p \geq 0.10$;*: $p < 0.10$; **: $p < 0.05$; ***: $p < 0.01$). The fit of the entire estimated model to the input correlation matrix *S* is indicated by LISREL via a chi-square test, the Goodness of Fit Index ($0 \leq GFI \leq 1$) and the Adjusted Goodness of Fit Index ($0 \leq AGFI \leq 1$) (Jöreskog and Sörbom, 1993). The computed chi-square value of 20.35 with 26 degrees of freedom coincides with a probability of fit of 78% (p=0.78), which is rather good but not excellent (p>0.90). This result is supported by the computed values of GFI and AGFI of 0.95 and 0.89, respectively.

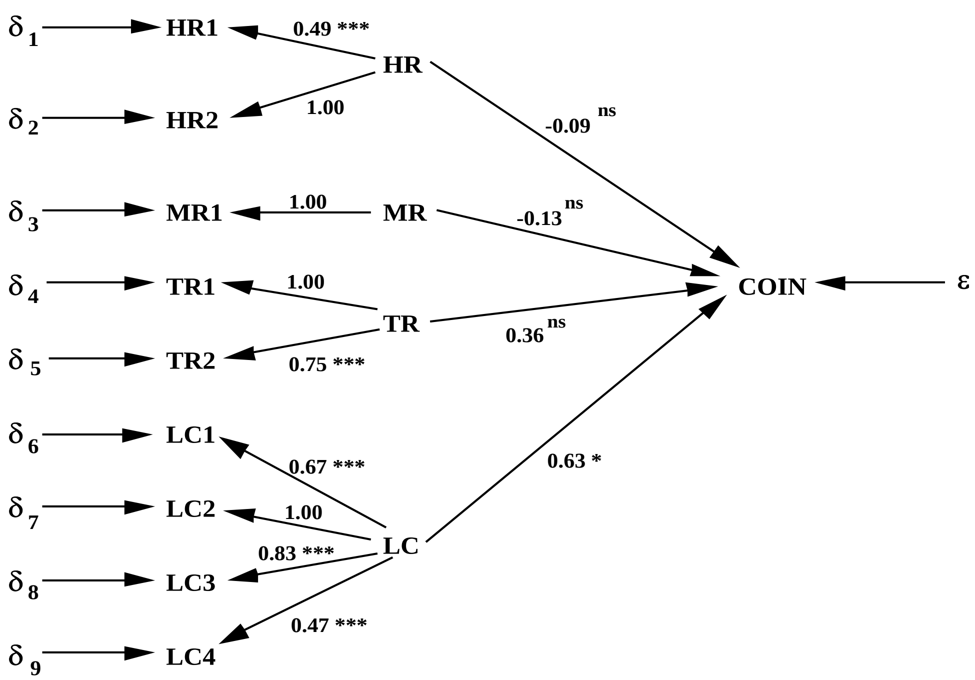


Figure 2 Estimates of the measurement and structural relations in the specified LISREL model.

Table 3 Estimated variances and covariances of the independent unobserved latent variables, the measurement errors in their observed indicators and the regression error

independent unobserved latent variables		*measurement and regression errors*	
var (HR) = 0.83 ^{ns}	cov (LC,HR) = 0.98 ***	var (δ_1) = 0.81 **	cov (δ_5, δ_1) = 0.40 *
var (MR) = 0.98 ***	cov (LC,MR) = 0.58 ***	var (δ_2) = 0.17 ^{ns}	cov (δ_6, δ_2) = -0.97 ***
var (TR) = 1.00 ***	cov (LC,TR) = 0.79 ***	var (δ_3) = 0.02 ^{ns}	cov (δ_6, δ_3) = 0.60 **
var (LC) = 1.00 ***		var (δ_4) = 0.00 ^{ns}	cov (δ_9, δ_1) = 0.49 *
		var (δ_5) = 0.44 ^{ns}	cov (δ_9, δ_3) = 0.47 *
		var (δ_6) = 0.55 ^{ns}	
		var (δ_7) = 0.00 ^{ns}	
		var (δ_8) = 0.31 ^{ns}	
		var (δ_9) = 0.78 **	
		var (ε) = 0.30 ^{ns}	

5.2.1 Measurement model

The estimates of the effects of the unobserved latent variables HR, MR, TR and LC, which represent the concepts Human Resources, Managerial Resources, Technological Resources and Learning Capability depicted in Figure 1, on their observed indicators are presented on the left side of Figure 2. All these effects are significantly different from zero ($p < 0.01$) thereby indicating that the sets of indicators of the unobserved latent variables are sufficiently coherent and that the unobserved latent variables HR, MR, TR and LC are adequately measured.

It should be noted that the independent unobserved latent variable MR is only measured on the observed indicator 'average level of education of the management' and not on the observed indicator 'average age of the management'. The latter indicator of MR is left out in the final estimation of the LISREL model because during previous estimations of the model this indicator turned out to be uncorrelated with 'average educational level of the management' and all other observed indicators, thereby producing much noise in the estimated LISREL model. Apparently, the observed indicator 'average age of the management' does not represent the built up experience of the management very well. Also, the measurement errors in the observed values of HR1 and LC4 are substantial as indicated by the significance of their estimated variances in Table 3. This implies that the selection and/or measurement of observed indicators of the independent concepts can be further improved. Specific attention should be paid to the observed indicators whose measurement errors are strongly correlated independent of the estimated correlations specified to exist among the independent concepts.

5.2.2 Structural model

The LISREL estimates of the regression coefficients representing the hypothesized effects of HR, MR, TR and LC on COIN are presented in Figure 2. Additionally, Table 3 contains the estimates of the hypothesized covariations between LC and HR, MR and TR.

The estimated covariations between LC and HR, MR and TR are all significantly different from zero ($p < 0.01$). Therefore, the conceptualization that Human, Managerial and Technological Resources are partial constituent elements of the much broader concept of (organizational) Learning Capability is confirmed by these statistical results.

The estimated hypothesized effects of HR, MR, TR and LC on COIN explain 70% of the variation in COIN (1 - var(ε)). Only the hypothesized positive influences of TR and LC are confirmed by the estimates of the corresponding regression coefficients. The estimated effect of TR is not significant, which might be due to the small size of the sample of KIBS in the Dutch EIS industry where on this study is based (N=21). The hypothesized positive effects of HR and MR on the KIBS' engagement in co-innovation (COIN) are not confirmed. Both estimated effects are rather small and negative and strongly insignificant. Thus, their role in inducing co-innovation by KIBS firms in the Dutch EIS industry should be reconsidered. Although both Human and Managerial Resources are found to be related to the KIBS firms' Learning Capability, they are also found to be unrelated to their engagement in co-innovation. This implies that Human and Managerial Resources are only indirectly related to the KIBS firms' involvement in co-innovation as partial constituent elements together with Technological Resources of their Learning Capability. A conclusion about whether Technological Resources are directly affecting the KIBS firms' involvement in co-innovation should be delayed until a re-estimation can be made of the LISREL model from an input matrix *S* based on a considerably larger sample of KIBS firms in a national EIS industry.

6. Discussion and conclusions

While the literature on KIBS has extensively mapped different patterns of firm innovation, no attempt was made to explain the ability of a KIBS firm to co-innovate with client firms (Muller and Doloreux, 2009). Our study contributes both an original theoretical model and a statistical study of a specific KIBS sector, with the caveat that the statistical results should be regarded as tentative because of the small sample size.

The model presented in this paper is grounded in the resource-based view of the firm, where resources represent firm knowledge bases and each firm is characterized by a specific portfolio of resources. Given that the core activity of KIBS firms is to develop, adapt and transfer knowledge, the theoretical model attaches a paramount role to the learning capability. This capability was expected to be critical in instances of co-innovation that require not only sheer knowledge provision, but more importantly, knowledge generation capabilities.

The model was tested on a sample of 21 Dutch environmental investigation service companies, offering a disaggregated analysis of a specific KIBS sector. The results provide insights into the validity of our theoretical model.

In support of the prediction that co-innovation is a particular type of innovation that requires specific abilities, we found that not all KIBS firms engage in co-innovation. Those firms that do engage in co-innovation are not necessarily the largest ones. While interactivity is a generic property of service provision, not all firms engage in interactive learning and co-produce innovations. This variation in co-innovation is explained by 70% of the effects of variations in learning capability, technological resources, managerial resources and human resources among the KIBS firms.

As expected, learning capability is strongly related to the ability of KIBS firms to co-innovate. This relation is so strong that it dwarfs all other effects. Human, managerial and technological resources do not show significant direct relations with co-innovation, even though they are strongly correlated with learning capability. Although the direct links among human, managerial and technological resources and co-innovation are not confirmed, we do find that our model has a good fit to the sample data utilized. This supports the inclusion of the chosen variables in the theoretical model.

Our empirical study has focused on a specific set of service firms, EIS firms, which can be characterized as technical KIBS. With regard to the relation between technological resources and the ability to co-innovate, a positive but insignificant effect of the former on the latter concept was found. Future research based on a larger sample of firms may therefore be expected to confirm the hypothesized positive relation. The hypothesized positive relations between human and managerial resources and the ability of EIS-KIBS firms to co-innovate are disconfirmed by their estimates.

Although the measurement of the concepts of human resources and learning capability can be further improved by reconsidering one of their indicators (i.e. HR1 and LC4), the measurement model represents the independent concepts of human, managerial and technological resources and learning capability (HR, MR, TR and LC) rather well (see Section 5.2.1). The indicators were chosen in line with insights from the organizational learning literature and capture firm efforts at better managing knowledge but they only capture organizational knowledge and learning capabilities indirectly (see Criscuolo et al., 2007 for a discussion of the empirical challenges in measuring capabilities).

Another problem is indicated by the high estimates of the correlations between the independent latent variable representing the concept of learning capability and the independent latent variables representing the concepts of human and technological resources. These high correlations are indicative of multicollinearity of these three independent concepts. Consequently, the concepts of human, managerial and technological resources and learning capability of EIS-KIBS firms should be reconsidered in terms of definition of empirical domains to which they apply and independence of those domains in future research. In this study, the empirical domains of human, managerial and technological resources and learning capability of KIBS firms are centered around knowledge and knowledge management, thereby creating a potential overlap of these domains. Such an overlap of empirical domains translates in multicollinearity and contamination of effects in the results of statistical analyses. This is a challenge of definition and demarcation of concepts that should be further investigated in future research.

Despite the limitations discussed above, our results are already of value to managers of service companies. The findings indicate that learning capability and innovative potential are strongly related to investment in knowledge management and knowledge management systems, such as client and project databases. Such systems allow KIBS firms to take stock of heterogeneous experiences and mobilize organizational knowledge for new endeavors.

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Appendix A: The input correlation matrix *S*

	COIN	HR1	HR4	MR2	TR1	TR2	LC1	LC2	LC4	LC9
COIN	1									
HR1	0.3681	1								
HR4	0.4949	0.4005	1							
MR2	0.2381	0.3515	-0.0629	1						
TR1	0.9894	0.1079	0.1416	0.1151	1					
TR2	0.4674	0.3962	0.3054	0.2740	0.7928	1				
LC1	0.5224	0.2546	-0.3095	0.9910	0.5624	0.3915	1			
LC2	0.9498	0.3476	0.9287	0.6558	0.8866	0.5628	0.9152	1		
LC4	0.5436	0.5361	0.9917	0.3835	0.4142	0.6953	0.2312	0.9748	1	
LC9	0.0622	0.7083	0.3310	0.7427	0.3386	0.2957	0.3763	0.7299	0.4638	1