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The Impacts of Knowledge Interaction with Manufacturing Clients on KIBS Firms Innovation Behaviour

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Abstract

Knowledge-intensive business services (KIBS) have been posited to play a critical role as innovation agent and knowledge broker in the new economy. While a substantial part of the literature on KIBS stresses their function as an innovation agent to their clients' innovation process and their contributions to knowledge transfer and diffusion in innovation systems, little attention has been paid to the internal innovation dynamics of KIBS firms. However, the interactive service relationship between KIBS firms and their clients is essentially a bilateral learning process that is supposed to also expand the innovation capabilities of KIBS firms. Based on a sample of 181 KIBS firms in Singapore, we investigate the specific impacts of client linkages on KIBS firms' innovation behaviour. We find that KIBS firms that engage in providing innovation support to manufacturing clients exhibit higher level of innovation behaviour. However, client size is not a significant determinant of KIBS innovation. These results are further confirmed by the importance of social capitals and spatial proximity for KIBS firms' successful innovation support provision to manufacturing clients.

Keywords: knowledge-intensive business services (KIBS), knowledge interaction, innovations systems

JEL classification: O30, O31, O32

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1 Introduction

There is a clear trend towards more knowledge-intensive manufacturing and services across the OECD countries, with a growing recognition of the importance of knowledge as a critical source of competitive advantage not only at firm level but also at country level. In this knowledge intensification process, knowledge-intensive business services (KIBS), such as IT and consulting services, have experienced the fastest growth and become increasingly important sources of innovation. Accordingly, increasing attention has been paid to the innovation activities in services and particularly in KIBS, and the role of KIBS in national innovation systems. Miles *et al.*'s often-cited work (1995) characterized KIBS as user, carrier and source of innovation. The final report from the European SI4S project concluded that KIBS play a key role in transforming client firms into dynamic learning organizations (Hauknes 1998). Den Hertog (2000) illustrated that KIBS are critical for facilitating innovation across the economy, and thus take an important role in national innovation systems as innovation agent.

However, there are several gaps in the burgeoning KIBS literature. First, while a substantial part of the literature on KIBS stresses their function as an innovation agent to their clients' innovation process and their contributions to knowledge transfer and diffusion in innovation systems, little attention has been paid to the internal innovation dynamics of KIBS firms. We argue that the interactive service relationship between KIBS firms and their clients is essentially a bilateral learning process that is supposed to also expand the innovation capabilities of KIBS firms. Second, the service relationship between KIBS firms and their clients is manifold, and different forms of service interaction may have different implications for their respective innovation behaviour. This question has not been adequately addressed and tested in the literature. Third, investigations of KIBS innovation remain highly exploratory, and empirical evidence is still incomplete and anecdotal in nature. There is still little econometric analysis about how KIBS firms interact with their clients in the process of knowledge co-production and how this knowledge interaction may shape their own innovation activities. Fourth, research on services innovation in the non-OECD context is still rare, although some exceptions do exist, e.g., the survey of services innovation in Hong Kong by Chan *et al.* (1998).

Muller and Zenker's study (2001), among the first, provided empirical support to the important 'virtuous innovation circle hypothesis' that the interaction between KIBS firms and their clients should mutually contribute to their respective innovation capabilities. These results were based on a French and German sample showing that interacting KIBS firms and manufacturing SMEs had a higher propensity to innovate than those that were not interacting. Although Muller and Zenker's empirical evidence is encouraging, one major weakness is that their study was based on direct chi-square test, without controlling for many other factors which would also shape KIBS firms' innovation behaviour. Moreover, it did not investigate the complex process of knowledge interaction between KIBS providers and clients. Instead, they used a rather vague measure of the presence of 'innovation-related interaction' (i.e., dummy variable) which was not clearly defined.

This paper focuses on the innovation behaviour of KIBS firms in their own right rather than their supporting role as the innovation agent for their clients. The aim of this paper is to provide fresh empirical evidence from Singapore, a non-OECD country, on how knowledge interaction with manufacturing clients can influence KIBS firms' innovation behaviour. We define knowledge interaction as how frequently KIBS firms provide four types of innovation support to manufacturing clients: product innovation, process innovation, organizational innovation and market development. Our results show that KIBS firms engaging in the provision of innovation support to manufacturing clients exhibit higher level of innovation behaviour. However, client size is not a significant determinant of KIBS innovation. These results are further confirmed by the finding that spatial proximity, overlapping knowledge base, and frequent personal contact are prominent factors for the successful provision of innovation support to manufacturing clients.

2 Literature review

2.1 Knowledge-intensive business services

In late 1990s, there have been significant research efforts directed to a particular type of services, the knowledge-intensive business services (KIBS). The KIBS sector constitutes one of the characteristics of the rise of knowledge-based economy (Muller and Zenker 2001), and is one of the most dynamic components of the services sector in most industrialized countries (Strambach 2001).

Miles *et al.* (1995: 18) defined KIBS as services that involve 'economic activities which are intended to result in the creation, accumulation or dissemination of knowledge'. Another general definition is from Muller (2001: 2): 'KIBS can be described as firms performing, mainly for other firms, services encompassing a high intellectual value-added'. Based on Miles *et al.*'s (1995) extensive discussion of KIBS, den Hertog (2000: 505) provided a more comprehensive definition: 'private companies or organizations who rely heavily on professional knowledge, i.e., knowledge or expertise related to a specific (technical) discipline or (technical) functional domain to supply intermediate products and services that are knowledge based'. The working definitions of KIBS vary considerably in the literature. Following Miles *et al.* (1995) and den Hertog (2000), we include three major KIBS sectors in our study: IT and related services; business and management consulting; and engineering and technical services (see appendix I for a detail decomposition).

KIBS are defined on the basis of high client intensity and knowledge interaction in services provision. KIBS may or may not be technology intensive.[1] What is important is that the definition of KIBS provides a platform to study a group of services which is very actively integrated into innovation systems by joint knowledge development with their clients, and which consequently create considerable positive network externalities and possibly accelerate knowledge intensification across economy. KIBS firms' innovation efforts extend far beyond their internal organizations to the service relationship and directly into the domain of service clients by providing

1 Miles *et al.* (1995: 29-30) distinguished between P-KIBS and T-KIBS. P-KIBS are 'traditional professional services, liable to be intensive users of new technology' (such as marketing/advertising services, business and management consulting services, legal and accounting services and so on). T-KIBS 'are related to emerging technologies and technological challenges' (such as IT related services, engineering services, R&D consulting services and so on).

competence-enhancing knowledge services to their clients, i.e., to ‘foster knowledge development elsewhere in the economy’ (Miles *et al.* 1995: 25).

2.2 The role of KIBS in innovation systems

The positive effects of KIBS firms as the innovation agent have been widely discussed in the recent literature, for both technology based and non-technology based KIBS. Bessant and Rush (1995) demonstrated that KIBS were critical to promote the adoption of Advance Manufacturing Technology (AMT) by supporting the selection and implementation of innovations in their manufacturing clients. In Howells’ (2000) case study, contract R&D services were not just playing a peripheral role in the innovation process, but were often actively involved in technical specification and product design for manufacturing firms. Moreover, in some cases, R&D service firms took the lead by tapping manufacturing firms’ technical inputs and manufacturing capability to realize their own innovations in the market.

The SI4S project summarized three functions that KIBS play in innovation systems (e.g., Hauknes 1998: 54):

i) the facilitator of innovation when a KIBS firm supports a client firm in its innovation process, but the innovation at hand does not originate from this KIBS firm;

ii) the carrier of innovation when a KIBS firm plays a role in transferring existing innovations from one firm or industry to the client firm or industry. However, the innovation at hand does not originate from this particular KIBS firm;

iii) the source of innovation when a KIBS plays a major role in initiating and developing innovations in the client firm.

Den Hertog (2000) also concluded that by co-producing innovation, KIBS operate as catalysts to promote the fusion between generic explicit knowledge dispersed in the economy and more tacit knowledge located in the firms or sectors they service. He further boldly suggested that by creating and combining knowledge resources in innovation systems, KIBS are gradually evolving into a second knowledge infrastructure alongside the more institutionalized knowledge infrastructure of universities and public research institutes.

3 Hypotheses formulation

The above literature review shows that most KIBS studies are dominated by concerns about how they affect the innovation process of clients’ firms. However, KIBS firms and their clients often work in a symbiotic relationship, and the knowledge interaction between KIBS firms and their clients is essentially a bilateral learning process that benefits both KIBS users and providers. This paper focuses on how the knowledge interaction between KIBS firms and their clients (manufacturing firms in our case) can also shape KIBS firms’ innovation behaviour.

3.1 Knowledge interaction with manufacturing clients

The importance of knowledge interaction for innovation was initially emphasized in the interactive innovation process models, e.g., Kline and Rosenberg's chain-linked model (1986), Lundvall's user-producer interaction (1988), and Rothwell's fifth generation innovation process (1992)—the systems integration and networking model (SIN). These models go beyond the traditional linear model by focusing on the internal interaction across different functional areas or innovation phases, as well as the external interaction with network partners for knowledge creation and transfer.

Interactive learning is also central to the national innovation system literature. Lundvall (1992: 2) defined the innovation system as 'a system of innovation constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge'. This systemic understanding of the innovation process suggests that firms generate their innovations through a complex interplay with various actors, such as buyers, suppliers, competitors, R&D institutes/universities, and government institutions. These dynamic learning and interactive innovation theories are particularly pertinent to KIBS since the importance of KIBS in innovation systems just lies in their linkages with other actors as discussed earlier.

On the one hand, KIBS firms integrate different areas of knowledge and competencies to solve their clients' innovative problems. On the other hand, the interactive innovation theory suggests that knowledge-flows between KIBS firms and their clients are not unilateral: KIBS firms also receive knowledge from the interaction with their clients to enhance their own knowledge base. A three-stage knowledge processing model for this knowledge interaction was proposed by Strambach (2001) and Muller and Zenker (2001): (i) knowledge acquisition—KIBS firms acquire knowledge (tacit and explicit) in the course of interaction process that takes place when the service is provided; (ii) knowledge recombination—KIBS firms combine knowledge gained from interaction with existing knowledge, and new knowledge is generated through this knowledge recombination/codification process, and the overall absorptive capacity is increased for the next round of knowledge processing; (iii) knowledge diffusion—KIBS firms apply the new knowledge into new service products or processes which open up new opportunities for them to interact with and transfer knowledge to their clients. It is evident that this is an iterative, continuous and reciprocal process in which the knowledge interaction expands KIBS firms' knowledge base which, in turn, leads to new possibilities of interaction.

Similarly, Muller (2001) suggested that KIBS firms can develop their own knowledge base and innovation capability through interaction with manufacturing SMEs in terms of better integration into innovation systems and better activation of internal/external innovation resources. Moreover, knowledge interaction with manufacturing clients can also function as a demand-pull factor to force KIBS firms to continually build up new competence and to catch up with the latest development in their fields of knowledge (Strambach 2001).

In this paper, we measure the knowledge interaction of KIBS firms in terms of the frequency of their innovation support to manufacturing clients. This measure is reasonable since interactive learning implies the penetration of organization boundaries. We propose that knowledge interaction with manufacturing clients can stimulate KIBS firms' innovation in their own right. Specifically we hypothesize that:

KIBS firms that provide innovation support to manufacturing firms show higher levels of innovation behaviour than KIBS firms that do not provide innovation support to manufacturing firms. *[H1]*

We use a number of indicators to measure the innovation behaviour of KIBS firms, such as propensity to innovate or to do R&D, the propensity to collaborate with R&D institutes/universities for innovation, innovation/R&D spending intensity, diversity of innovation activities, and new services intensity (see next section for definitions).

3.2 Big client size

The demand-pull hypothesis (Schmookler 1966) in mainstream innovation studies suggests that client size could be another determinant of KIBS innovation. KIBS firms may derive legitimacy or status from their affiliation with big customers (Podolny and Page 1998). On the one hand, the derived legitimacy helps KIBS firms attract new customers and retain existing customers which generate cash flows for innovation. On the other hand, the enhanced status of doing business with big customers may result in improved access to external resources for innovation (e.g., financial resources, support from research institutes/universities). Moreover, large client size implies bigger and more stable transaction volumes which make innovation more profitable due to economies of scale and scope in innovation spending. Big client size also makes it easier to predict future changes in demand, and makes innovation less risky (Peters 2000). Christensen and Bower (1996: 199) argued in their case study of global disk drive industry:

> When a proposed innovation addresses the needs of small customers in remote or emerging markets that do not supply a significant share of the resources a firm currently needs for growth and survival, firms will find it difficult to succeed even at innovations that are technologically straightforward.

However, doing business with big clients may not stimulate the innovation activities of KIBS firms for at least the following two reasons: (i) high client intensity and customization in KIBS provision severely limit economies of scale and scope in innovation investment; (ii) the interactive learning nature of KIBS innovation suggests that social capitals (Nahapiet and Ghoshal 1998; Uzzi 1997), such as a shared language, overlapping knowledge structures, and a common cognitive frame, are particularly important for KIBS innovation, but doing business with big clients on the basis of discrete market exchange does not foster these conducive conditions. We argue that client size does not capture the positive feedback effects from 'learning by interacting' or 'learning by networking' which characterize KIBS innovation. Therefore, we hypothesize that

KIBS firms that do business with big clients do not show higher levels of innovation behaviour than KIBS firms that do not do business with big clients. *[H2]*

4 Data and methods

4.1 Development of KIBS in Singapore

KIBS actually cover a wide range of services, and there has been no uniform operationalization of KIBS in the literature. Particularly the working definition based on industrial classification may miss the emerging activities that can be regarded as KIBS across industries (Miles *et al.* 1995). Based on our rather restrictive KIBS operationalization, we construct a rough picture of the evolution of KIBS in Singapore over the 1990s (Table 1 and Table 2). A steady growth of KIBS is observed. Share of KIBS employment in services increased from 12.9 per cent in 1990 to 17.3 per cent in 1999, and the corresponding share of KIBS value added increased from 9.4 per cent to 13.8 per cent. In particular, a strong trend of growth is found for IT and related services.

Table 1
Share of KIBS employment in the services sector (%)

	1990	1991	1992	1993	1994 [1]	1995	1996	1997	1998	1999
KIBS	12.9	13.6	13.5	14.0	15.1	16.2	15.2	15.8	15.9	17.3
Share of IT and related services in KIBS	14.2	14.5	15.1	16.1	16.3	16.4	18.5	18.9	20.0	23.8
Share of business and management consulting in KIBS	54.7	54.9	55.6	52.9	53.9	54.9	53.6	51.4	49.4	50.6
Share of engineering and technical services in KIBS	31.1	30.6	29.2	31.0	29.9	28.8	27.9	29.7	30.6	25.7
Total [2]	100	100	100	100	100	100	100	100	100	100

Notes: [1] Year 1994 data not available, based on interpolation.
[2] Figures may not add up to 100 due to rounding.

Source: Calculated from *Economic Surveys Series* (various years).

Table 2
Share of KIBS value added in the services sector (%)

	1990	1991	1992	1993	1994 [1]	1995	1996	1997	1998	1999
KIBS	9.4	9.6	9.9	10.0	10.8	11.6	11.0	12.3	12.9	13.8
Share of IT and related services in KIBS	13.5	16.0	17.8	17.7	18.4	19.0	20.6	20.9	21.6	23.4
Share of business and management consulting in KIBS	57.4	56.6	54.4	54.2	53.7	53.2	52.0	52.6	52.3	53.3
Share of engineering and technical services in KIBS	29.2	27.4	27.8	28.2	28.0	27.7	27.4	26.5	26.1	23.3
Total [2]	100	100	100	100	100	100	100	100	100	100

Notes: [1] Year 1994 data not available, based on interpolation.
[2] Figures may not add up to 100 due to rounding.

Source: Calculated from *Economic Surveys Series* (various years).

4.2 Data source

Data for this study were drawn from a national innovation survey focusing on KIBS in Singapore conducted through a university research centre in 1999. Since there was no available comprehensive list of KIBS firms, a variety of business directories were used to construct the KIBS sample.

Structured survey questionnaires were sent to the CEOs of 3728 KIBS firms. A total of 181 valid responses were achieved, yielding response rate of only 4.9 per cent. The response rate was considerably lower than the typical range of 12 per cent and 10 per cent for mail surveys targeted at senior executives (Hambrick *et al.* 1993). Nevertheless, we found no systematic bias in the respondent firms vs. the population in terms of industry distribution, and the absolute sample size (181) was adequate for hypothesis testing in this study.

Some survey instruments were adopted from the OECD 'Oslo Manual' (OECD-EUROSTAT 1997) wherever applicable. In particular, the distinction between product and process innovation was kept.[2] This distinction is widely used and seems to be working well in services innovation surveys (e.g., Sirilli and Evangelista 1998; Hipp *et al.* 2000). Indeed, the Oslo Manual does not rule out application of its procedure to services closely related to manufacturing (Miles 1995). On the other hand, to study the specific characteristics of the innovation process of KIBS firms, several additional questions about the innovation support of KIBS firms to manufacturing clients were asked.

4.3 Variables

KIBS firms were asked how often (from 0 [not at all] to 4 [frequently]) they supported four types of innovation activities in manufacturing clients: product innovation, process innovation, organizational innovation, and market development.[3] Factor analysis was used to construct a synthetic indicator. These four types of support were found to load onto one factor (72 per cent variance explained, Cronbach alpha = 0.87). We named this factor as innovation support which was the linear combination of the original variables (equation support 1). The standardized values of innovation support were used in the following analysis.

Innovation support = 0.292 * product innovation support + 0.303 * process innovation support + 0.288 * organizational innovation support + 0.298 * market development support (1)

2 Close interaction between production and consumption (co-terminality) is thought to cause difficulties in distinguishing between product and process innovation. However, Sirilli and Evangelista (1998) found that only a quarter of the innovating service firms in their Italian survey were unable to distinguish between product and process innovation. Hipp, Tether and Miles (2000), and Preissl (2000) also found that the distinction between product and process innovation was reasonably robust in empirical investigations, but it was difficult to maintain a clear distinction between process and organizational innovation in services.

3 Since internal innovation and innovation support to manufacturing clients of KIBS firms can be highly interdependent, to resolve the possible ambiguity in answering the questionnaire, we reminded respondents at the beginning of the innovation support section: 'This section is about innovations introduced by your manufacturing clients. Please do not refer to innovation in your own enterprise any longer!'

Table 3
Variables of the KIBS sample

Product innovation	1 if introduced new or substantially improved services over the last three years, 0 otherwise
Process innovation	1 if adopted new or substantially improved methods of service provision over the last three years, 0 otherwise
Innovation	1 if either product or process (or both) innovation takes value of 1, 0 otherwise (when product innovation = 0 and process innovation = 0)
Diversity of innovation activities	Number of different innovation activities engaged in: (a) R&D; (b) acquisition of R&D services; (c) acquisition of machinery and equipment linked to innovation; (d) acquisition of software and other external technology linked to innovation; (e) preparations to introduce new or significantly improved services or methods to deliver them; (f) training directly linked to technological innovation, (g) market introduction of technological innovations; (h) adoption of e-commence applications, if innovation = 1 (assuming each type of innovation activity has the same weight). 0 if innovation = 0
Innovation spending intensity	Total expenditure on the above innovation activities as a per cent of total sales if innovation = 1, 0 if innovation = 0
R&D	1 if doing R&D in Singapore, 0 otherwise
R&D spending intensity	R&D spending in Singapore as a per cent of total sales if R&D = 1, 0 if R&D = 0
New services intensity	% of total annual sales from new or substantially improved services introduced over the last three years, 0 if product innovation = 0
Collaborate with R&D institutes/universities	1 = yes, 0 = no
Innovation support	A composite indicator based on how frequently the KIBS firm provides four types of innovation support to manufacturing firms over the last three years: product innovation, process innovation, organizational innovation, and market development (from 0 [not at all] to 4 [frequently]). Alpha = 0.87
Strategic orientation	Importance of the following strategic factors for the sales success: (a) price, (b) quality; (c) on time fulfilment; (d) large-scale of services; (e) broad scope of services; (f) novelty of product; (g) short delivery time; (h) flexibility upon customer request; (i) multiple distribution channels; (j) marketing and communication; (k) environmental acceptability. 1 = little influence, 5 = most decisive.
Big client	How frequently doing business with private sector client of 500 employees and more. 0 = not at all, 4 = frequently
Foreign firm	1 if foreign company, 0 otherwise
Industry dummies	IT and related services (reference category), business and management consulting, technical and engineering services
Firm size	Total employment
Firm size square	Square of total employment/100
Firm age	1999-founding year
Internationalization	Share of foreign turnover for the latest business year
Human capital intensity	Percentage of university graduates and diploma holder in total employment

Measures for the key variables are showed in Table 3. Both R&D intensity and innovation intensity indicators were used as dependent variables. Compared to manufacturing innovation, services innovation appears to draw less on R&D, and the management of services innovation is often *ad hoc* in nature, e.g., without the R&D

department and managers usually found in large or technology-intensive manufacturing firms (Sundbo 1997).

Industry dummies, firm nationality (foreign or local), firm age, firm size, degree of internationalization, human capital intensity, and firm strategic orientations were included as control variables.

Most empirical studies in manufacturing have confirmed the Schumpeterian hypothesis that firm innovation increases with firm size (Cohen 1995). However, since the economies of scale are very limited in services, size effect may not be significant. The quadratic term (firm size square) was also included in order to account for the possible non-linearity in the relationship between innovation and size.

Barras' (1986) influential 'reverse product cycle' (RPC) model proposes that new technologies are adopted by service firms initially to improve the efficiency of service production or delivery, then in the second phase to improve service quality and flexibility, and finally in the third phase to introduce new service products. Despite the fact that Barras' model provides a useful conceptual framework for analysing how technology adoption, especially ICT adoption, impacts services innovation, it has been widely criticized especially for its technology determinism (Buzzacchi *et al.* 1995; Uchupalanan 2000). Innovations are formulated within the framework of firm strategy, and they are primarily determined by the strategic situation of the firm (Sundbo 1997). Strategic choice does exist in services innovation. In this study, KIBS firms' self-reported importance of strategic factors for the sales success was used as proxy for their strategic orientations.

4.4 Methods

Logistic regression was used to test the impacts of innovation support on KIBS firms' propensity to innovate, to do R&D, and to collaborate with R&D institutes/universities, since the dependent variables were binary. The logistic model estimates the impact of independent variables on the odds ratio for the dependent variables to be one. Taking the propensity to innovate as an example, the logistic model takes the form of equation (2):

$$LN \frac{\Pr(innovate)}{1-\Pr(innovate)} = \beta_0 + \beta X \qquad (2)$$

Where Pr is probability, and *X* is a vector of independent variables.

When dependent variables were innovation spending intensity, R&D spending intensity, diversity of innovation activities, and new services intensity, the Tobit model was used because a considerable proportion of the sample firms reported no innovation or no R&D activity, i.e. the sample was left censored. Taking innovation-spending intensity as an example, the Tobit model can be expressed as equation [3]:

$$\begin{aligned}&\textit{Innovation spending intensity} = \beta_0 + \beta X \quad \textit{if Innovation spending intensity} > 0\\ &\textit{Innovation spending intensity} = 0; \textit{ otherwise} \qquad (3)\end{aligned}$$

Where *X* is a vector of independent variables.

A coefficient in the above standard Tobit regression is a weighted average of two effects: (i) the probability that a dependent variable takes positive values and (ii) the increase/decrease in the dependent variable given it is positive. Heckman's (1976) two-step model can solve this ambiguity, taking innovation spending intensity as an example: (i) obtain the inverse Mills ratio from the probit regression (innovation =1 or 0) using all observations; (ii) the inverse Mills ratio is included as an additional variable to explain the variation in innovation-spending intensity, using the selected sample innovation = 1. This procedure is also called the Heckit method. However, the small sample size in this study may make the results of the second step not reliable (104 firms with innovation = 1; 47 firms with R&D = 1; and 84 firms with product innovation = 1). Therefore, we only used Heckit results as a comparison with Tobit results.

5 Results

5.1 Hypothesis testing

Results of logistic regression are showed in Table 4. Model 1 examines the determinants of overall innovation propensity. The positive coefficient of innovation support ($p < 0.05$) in model 1 suggests that the mutual enhancing effects of knowledge interaction make KIBS firms providing innovation support to manufacturing clients more likely to innovate. As expected, the impacts of client size are not significant. Models 2 and 3 distinguish between product innovation and process innovation. Sharp differences among the determinants of product innovation and process innovation can be observed. In particular, the positive feedback effects from innovation support are only found for product innovation, not for process innovation. One possible explanation from the manufacturing innovation studies is that product innovation may require more feedback and knowledge exchange with users (von Hippel 1988; Lundvall 1988), but process innovation may require more support and interaction with equipment suppliers. Model 4 shows that innovation support has marginally significant ($p = 0.088$) impacts on KIBS firms' R&D propensity. As expected, client size has no impacts on KIBS firms' R&D propensity. As for model 5, innovation support is found to have significant impacts on KIBS firms' propensity to collaborate with R&D institutes/universities. This result implies that those KIBS firms providing innovation support to manufacturing clients are better integrated into public knowledge infrastructures. This is possibly because KIBS firms also need to draw upon knowledge and competencies from R&D institutes/universities to solve their clients' innovative problems. Again, the coefficient of client size is not significant.

Several control variables also show significant impacts on KIBS firms' innovation behaviour. Firm size and human capital intensity are found to be important determinants of KIBS firms' propensity to engage in product innovation, but do not have significant impacts on the propensity to engage in process innovation. The impacts of internationalization are significant and positive for both product and process innovation, as well as R&D propensity, but not for the overall innovation propensity. The non-linear effects of firm size are found in model 2 and model 4. Regarding strategic orientations, a marketing and communication focus is found to significantly increase KIBS firms' propensity to innovate (process innovation specifically) and to collaborate with R&D institutes/universities.

Table 4
Logistic regression for KIBS firms' propensity to innovate and to do R&D [1, 2]

Controls	Innovation (1)	Product innovation (2)	Process innovation (3)	R&D (4)	Collaborate with R&D institutes/universities (5)
Management and business consulting	-0.678 (0.159)	-1.057** (0.030)	-0.373 (0.415)	-0.781* (0.093)	-1.346** (0.010)
Engineering and technical services	-1.220*** (0.008)	-1.864*** (0.000)	-0.531 (0.224)	-1.053** (0.026)	-0.298 (0.525)
Foreign firm	-0.106 (0.827)	-0.489 (0.331)	-0.714 (0.138)	-0.745 (0.157)	0.924* (0.072)
Firm age	-0.035 (0.213)	-0.055* (0.089)	-0.047* (0.094)	-0.034 (0.278)	-0.047 (0.138)
Firm size (employment)	0.024 (0.188)	0.051*** (0.007)	0.024 (0.121)	0.035** (0.019)	0.003 (0.844)
Firm size square	-0.008 (0.381)	-0.018** (0.036)	-0.009 (0.219)	-0.013* (0.055)	-0.001 (0.876)
Internationalization	0.009 (0.180)	0.016** (0.018)	0.013** (0.050)	0.011* (0.087)	0.001 (0.960)
Human capital intensity	0.011 (0.131)	0.021** (0.011)	0.009 (0.195)	0.003 (0.703)	0.008 (0.369)
Strategic orientation					
Marketing and communication	0.317** (0.026)		0.404*** (0.004)		0.542*** (0.002)
Big client	0.199 (0.123)	0.156 (0.249)	0.151 (0.222)	-0.128 (0.347)	0.059 (0.670)
Innovation support	0.413** (0.047)	0.482** (0.021)	0.295 (0.119)	0.325* (0.088)	0.438** (0.026)
-2 log likelihood	192.699	176.428	203.208	182.962	167.368
Nagelkerke R Square	0.348	0.446	0.309	0.185	0.269
Number of observations	181	181	181	181	178

Note: [1] In order to save degree of freedom, insignificant strategic orientation variables were dropped using stepwise regression.
[2] Two-tailed test. P value in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5 presents the Tobit regression results. In model 6, innovation support has marginally significant impacts ($p = 0.061$) on KIBS firms' innovation spending intensity, and the coefficient of client size is not significant. Similar results are found in model 7 (regression for diversity of innovation activities). Regarding model 8 (regression for R&D spending intensity), the coefficient of innovation support is positive but not significant, while the coefficient of client size remains insignificant. Model 9 examines the determinants of new services intensity. It is found that KIBS firms providing innovation support to manufacturing clients may have higher new services intensity. Again, the impacts of client size are insignificant.

Table 5
Tobit regression for KIBS firms' innovation and R&D spending intensity, diversity of innovation activities, and new services intensity [1, 2]

Controls	Innovation spending intensity (6)	Diversity of innovation activities (7)	R&D spending intensity (8)	New services intensity (9)
Management and business consulting	-9.792** (0.044)	-1.585** (0.017)	-17.724*** (0.002)	-26.238*** (0.004)
Engineering and technical services	-15.367*** (0.002)	-2.420*** (0.000)	-18.264*** (0.002)	-37.102*** (0.000)
Foreign firm	-11.595*** (0.022)	-0.699 (0.316)	-12.602* (0.054)	-10.970 (0.258)
Firm age	-0.571* (0.063)	-0.052 (0.208)	-0.265 (0.484)	-1.131* (0.065)
Firm size (employment)	0.251* (0.093)	0.059*** (0.005)	0.390** (0.026)	0.365 (0.190)
Firm size square	-0.108 (0.119)	-0.024** (0.011)	-0.167* (0.062)	-0.117 (0.360)
Internationalization	0.149** (0.029)	0.019** (0.047)	0.212** (0.011)	0.206 (0.112)
Human capital intensity	0.144* (0.066)	0.021** (0.049)	0.075 (0.423)	0.333** (0.039)
Strategic orientation				
Quality			5.852* (0.089)	
Flexibility upon customer request	-3.578* (0.062)			
Marketing and communication	3.583** (0.021)	0.457** (0.030)		8.401*** (0.005)
Big client	1.328 (0.331)	0.145 (0.432)	-1.937 (0.233)	4.040 (0.114)
Innovation support	3.631* (0.061)	0.712*** (0.008)	3.647 (0.119)	7.327** (0.047)
Log likelihood	-515.844	-316.167	-256.442	-477.056
R square	0.225	0.313	0.234	0.260
Number of observations	181	181	181	181

Note: [1] In order to save degree of freedom, insignificant strategic orientation variables were dropped using stepwise regression.

[2] Two-tailed test. P value in parenthesis. * p < 0.10, **p < 9.05, ***p < 0.01.

Among the control variables, internationalization is found to be a significant determinant for both innovation and R&D spending intensity, and diversity of innovation activities; human capital intensity is found to be positively related to innovation spending intensity, diversity of innovation activities and new services intensity; and the non-linear effects of firm size are also found in two out of four regressions. In particular, the significant impacts of marketing and communication focus (six out of nine regressions) are remarkable here, although the use of stepwise regression makes this result less reliable. This result is consistent with the importance of customer orientation in services innovation.

Compared to the Tobit results, the corresponding Heckit results (not reported here) show that the impacts of innovation support are positive and significant on innovation spending intensity ($p = 0.051$) and diversity of innovation activities ($p = 0.073$), but not significant on R&D spending intensity and new services intensity. The impacts of client size are significant for none of the four Heckit regressions. It seems that conditional on a KIBS firm doing R&D or innovation, the impacts of innovation support on R&D or innovation intensity is relatively weaker compared to the impacts on its propensity to do R&D or innovation.

5.2 The process of knowledge interaction with manufacturing firms

To further confirm the hypothesis testing, we look into the process of knowledge interaction with manufacturing firms. We expect that social capitals, such as shared language/jargon, overlapping knowledge structure, and personal connections to be important for KIBS firms' successful innovation support to manufacturing clients. Following this logic, spatial proximity is also expected to be necessary to develop such social capitals.

Although ICT is reducing the importance of distance in service production, the need for physical proximity may still be necessary for knowledge interaction between KIBS firms and their clients. Knowledge interaction between KIBS and manufacturing firms is a complex learning and reframing process where trust and shared understanding should be constructed through rich communication. This is difficult to achieve if people are physically distant from one another. Heraud (2000: 4) has explained this paradox:

> … to a certain extent, the trend of de-materialization and the development of the techniques of communication should help the creative networks to get rid of distance; but at the same time it appears that complex cognitive processes need not only large flows of codified scientific and technical information, but also a lot of tacit knowledge for using and interfacing that information. Then proximity does matter, since building common tacit knowledge implies close contacts, at least at the beginning.

Table 6
Important factors for the successful provision of innovation support to manufacturing client [1]

	Percentage of KIBS firms indicating very important [2]
Location close to client	21.3
Frequent personal contact	47.5
Existence of similar qualifications	18.3
Complementary skills	31.7
Good knowledge of clients' industry	50.8

Note: [1] Among KIBS firms providing innovation support to manufacturing clients.
[2] 1 = not important, 5 = very important.

Table 7
Location of manufacturing client for innovation support [1]

	Percentage of KIBS firms having manufacturing client for innovation support in different locations
Singapore	90.2
ASEAN [2]	58.3
Other Asia	46.8
North America	32.3
Europe	27.4

Note: [1] Among KIBS firms providing innovation support to manufacturing clients.
[2] Association of South East Asian Nations.

Table 8
The importance of spatial proximity to client for product innovation support [1]

	Percentage of KIBS reporting spatial proximity is particularly important [2]
For any phase in product innovation support	71.0
(1) Market analysis	51.9
(2) Idea generation and feasibility assessment	44.4
(3) Front-end development	26.5
(4) Development and design	30.5
(5) Manufacturing process development and planning	20.6
(6) Market introduction	29.4
(7) IPR licensing and protection	6.7

Note: [1] Among KIBS firms providing innovation support to manufacturing clients.
[2] Firms can tick three phases at most.

Table 9
The importance of spatial proximity to client for process innovation support [1]

	Percentage of KIBS reporting spatial proximity is particularly important [2]
For any phase in process innovation support	75.5
(1) Diagnosis of process problems	42.9
(2) Process-related Idea generation and feasibility assessment	34.1
(3) Process-related front-end development	18.9
(4) Process development and design	21.9
(5) Organizational process re-design	20.0
(6) Process implementation and testing	35.0
(7) Process-related training of employees	44.4

Note: [1] Among KIBS firms providing innovation support to manufacturing clients.
[2] Firms can tick three phases at most.

As expected, among 63 KIBS firms reported that they provided at least one type of innovation support to manufacturing clients over the last three years, 47.5 per cent regard ‘frequent personal contact’, and 50.8 per cent regard ‘good knowledge of clients industry’ as very important factors for the successful provision of innovation support (Table 6). Although ‘location close to the client’ seems not to be important, Table 7 shows that most of KIBS firms’ manufacturing clients are indeed located in Singapore and the nearby ASEAN region.

Tables 8 and 9 further show the relative importance of spatial proximity over different phases in product and process innovation support. For product innovation support, spatial proximity is mostly frequently cited as important for ‘market analysis’ and ‘idea generation/feasibility assessment’. For process innovation support, spatial proximity is of greatest importance for ‘diagnosis of process problems’ and ‘process-related training of employees’. It thus appears that spatial proximity is important for the early phases of product innovation support, but for both early and late phases of process innovation support. In sum, this follow-up investigation confirms our hypothesis testing.

6 Discussion

6.1 Implications

Notwithstanding the small sample size, this study highlights a number of implications for public policy as well as innovation management. First, we recommend public policy makers to support and promote innovation in the services sector, especially the KIBS sector. Much of the public policies on promoting innovation are more geared towards manufacturing industries, especially in many NIEs where the manufacturing sector had traditionally been the key driver for rapid economic growth. A recent study in UK showed that innovating manufacturing enterprises were approximately five times more likely to participate in government innovation support programs than their counterparts in the services sector (Green *et al.* 2001). This result is echoed in our sample in that manufacturing firms are two times more likely to receive government support for innovation than KIBS firms.

Second, not only do a significant proportion of KIBS firms provide innovation support services to manufacturing clients, but that there is a significant positive association between the innovation intensities of KIBS firms and their engagement in this innovation support. Our findings highlight the need for policy makers to take a holistic, interactive system view of the effects of innovation policy. It is not enough to examine innovation policy for the manufacturing sector and the services sector in isolation from one another; instead, public policy makers need to focus on how to promote the learning interaction and knowledge transfer between the two.

Third, our results are highly consistent with the interactive learning theory. The service relationship between KIBS firms and their clients can take a variety of forms. For example, Tordoir (1993) distinguished three different modes of service interaction: (1) sparring relations where a non-expert client is guided by a KIBS specialist; these relations are most frequent in strategic and organizational problems solving; (2) jobbing relations where the client is itself an expert, directing the process of service provision; these relations are frequent in engineering and technical service provision; and (3) selling relations where the client buys 'boxed' service products embodying specialist expertise of the KIBS firm. Both sparring and jobbing relations are interactive, and 'as long as relations to some extent involve sparing and jobbing, the relation between the two parties may be characterized as a co-producing relation at a point where the generic, horizontal expertise of the KIBS providers meets the vertical, specific and localized knowledge of the client' (Hauknes 1998: 53). On the contrary, selling relations are discrete and do not provide opportunities for interactive learning, especially for the party of KIBS firms. The insignificance of client size in the regression analysis may to some extent reflect this point of view. The interactive nature of KIBS innovation is echoed by our finding that social capitals are important for successful innovation support to manufacturing clients. This finding suggests that the management of KIBS provider-client relationship is critical to achieve the learning objectives for both parties.

6.2 Future research

Although our analysis adopts a systemic approach to study the impacts of service relationship on KIBS innovation behaviour, a number of limitations are identifiable. First of all, as Bilderbeek *et al.* (1998) pointed out, the services sector could be the major part of the demand of KIBS. For our sample, it is found that the manufacturing sector consists an average of 27 per cent of KIBS firms' sales, compared to 49 per cent from the services sector, and 16 per cent from the public sector. It could be useful to extend the framework of this study to investigate how KIBS firms interact with service clients and public clients. It is possible that the knowledge interaction process in these cases can be very different.

Moreover, it is difficult, if not impossible to construct an accurate statistical relationship between service interaction and measures of KIBS firms' performance. For our sample, we find no direct linkage between knowledge interaction and KIBS firms' performance, such as sales growth and employment growth. However, there is an indirect linkage where the performance impacts of knowledge interaction are transmitted through innovation spending intensity and new services intensity. It is very possible that the effects of knowledge interaction and the resulting higher levels of innovation behaviour may take time to unfold. Thus, a longitudinal study is desirable to capture the performance effects of this knowledge interaction.

Lastly, the knowledge interaction with manufacturing clients can also trigger organizational changes in KIBS firms. Organizational innovation is critical in determining service firms' competitiveness due to the intangible nature of most services (Miles 2000; Sirilli and Evangelista 1998). The bias towards technological innovation runs the danger of missing substantial parts of the innovation dynamics in KIBS. The practical difficulties to study organizational innovation in services do not negate its theoretical importance. How the knowledge interaction affect KIBS firms' organizational changes which in turn affect their performance should be addressed by future research.

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Appendix: Operationalization of KIBS according to Singapore Standard Industry Classification (SSIC)

IT and related services

721	IT consultancy
722	IT development
723	IT services
724	Maintenance and repair of office, accounting and computing machinery
729	Other IT and related services

Business and management consulting

7411	Legal activities
7412	Accounting, book-keeping and auditing activities; tax consultancy
7413	Market research and public opinion polling
7414	Business and management consultancy activities
7430	Advertising activities

Engineering and technical services

7421	Architectural and land survey activities
7422	Engineering activities
7423	Technical testing and analysis services
7424	Industrial design activities
731	Research and experimental development on natural science and engineering