Knowledge as a Contingency Variable: Do the Characteristics of Knowledge Predict Organization Structure?

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Abstract

This paper examines the validity of knowledge as a contingency variable. Building on recent advances in thinking about the dimensions of knowledge assets (Winter 1987, Zander and Kogut 1995), we argue that such dimensions might have an important influence on organization structure. More specifically, we focus on two dimensions of knowledge—observability and system embeddedness—and their influence over the level of unit autonomy and interunit integration in an international network of R&D units. Statistical analysis of questionnaire responses from 110 R&D unit managers show strong association between the dimensions of knowledge and organization structure. It also indicates partial support for the "fit" hypothesis in contingency theory.

The paper makes two important contributions to the knowledge management literature. First, we find support for the contingency logic, suggesting that effective organization design has to take into account the underlying characteristics of the firm's knowledge base. Second, we shed light on a relatively neglected dimension of knowledge that we call *system embeddedness*. This is the extent to which knowledge is a function of the social and physical system in which it exists. In the statistical analysis it emerges as a strong predictor of organization structure. Moreover, it also appears to be conceptually distinct from the tacit-articulate dimension that is normally emphasized. This allows us to speculate on four generic forms that a firm's knowledge might take, that we label integrated, isolated, opaque, and transparent. These are discussed using examples from the data.

(*Knowledge Management*; *Contingency Theory*; *R&D Management*)

This paper uses a contingency theory framing to examine the proposition that the characteristics of a firm's knowledge base have an important influence on its choice of organization structure. Traditionally, contingency theory has focused on such contingency variables as environmental uncertainty, firm size, and firm technology. Our approach is to build on recent advances in knowledge management to establish whether "knowledge" can be considered a useful contingency variable in its own right. Using questionnaire data from 110 R&D units in 15 multinational firms, we find strong support for this assertion. We also find evidence that the "fit" between knowledge characteristics and organization structure is related to performance, though this finding is less clear-cut.

The research has important implications for the measurement of different dimensions of knowledge. Working with the questions developed by Udo Zander and Bruce Kogut (Zander 1991, Kogut and Zander 1993, Zander and Kogut 1995), we focus on two aspects of knowledge, observability, and system embeddedness. *Observability* is defined as how easy it is to understand the activity by looking at and examining different aspects of the process or final product. *System embeddedness* is the extent to which the knowledge in question is a function of the system or context in which it is embedded (see next section for a discussion of these definitions). Our analysis suggests that system embeddedness is the stronger predictor of organization structure and, moreover, that the two dimensions are orthogonal. This insight suggests some important implications regarding the management of knowledge in large firms.

In terms of the empirical context of the research, we collected data from 110 R&D unit managers in 15 Swedish multinational firms. All these firms have their R&D activities dispersed among multiple locations, so it is a matter of some importance to decide how R&D work should be configured and coordinated. Some firms, such

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as Ericsson, operate a closely integrated network of "design centres" with high levels of interdependence between them. Other firms, such as Alfa Laval and ABB, give their individual R&D units much greater autonomy. The reasons for these different arrangements are many, but the logic suggested in this paper is that a critical one is the nature of the firm's knowledge base. Thus, we find that the more system embedded the knowledge, the greater the autonomy of the R&D unit and the less interunit integration between R&D units. We also show that the more observable the knowledge, the less interunit integration between R&D units.

The paper plays out the above ideas and findings in detail. In the following section we provide a background to contingency theory, and in particular to the literature looking at technology as a contingency variable. In the second section we examine the measurement of knowledge, which leads to the derivation of specific hypotheses linking the dimensions of knowledge to aspects of organization structure. Section 3 explains the research methodology. Section 4 describes the findings. Finally, in § 5 we discuss the implications of the research.

Theoretical Background

Contingency Theory

One of the major strands of thinking about organizations is contingency theory, which simply argues that there is no one best way of organizing—instead, the optimum organization structure depends on a number of contingency factors such as the complexity of the environment, the strategic positioning of the firm, or the technology it is using (Galbraith 1973, p. 2). Rather than accepting a deterministic logic ("all organizations should be centralized") or an every-case-is-different approach, contingency theorists argue that there is a middle ground in which it is possible to analyze the variation in organization structures in a systematic way. Among the principal contingency variables identified are environmental complexity (Burns and Stalker 1961, Lawrence and Lorsch 1967), organization strategy (Chandler 1962, Child 1972), technology (Thompson 1967, Woodward 1965), and organization size (Hickson et al. 1969).

Contingency theory "dominated the scholarly study of organizational design and performance" in the 1960s and 1970s (Van de Ven and Drazin 1985, p. 334), but in the 1980s it faced a variety of conceptual and empirical critiques (Gresov 1989, Schoonhoven 1981, Tosi and Slocum 1984, Van de Ven and Drazin 1985), and it subsequently lost ground to other theoretical perspectives. While contingency theory per se still has its adherents (e.g., Donaldson 1995), there is a shift in emphasis in the literature towards a so-called *configurational* approach in which superior performance is seen as a function of multiple interacting environmental and structural characteristics, rather than one or two primary contingencies (Galunic and Eisenhardt 1994, Gresov and Drazin 1997, Meyer et al. 1993, Van de Ven and Drazin 1985).

It is not the purpose of this paper to provide a thorough review or critique of contingency theory. Notwithstanding the shift in emphasis towards configurational thinking, our position is that contingency theory offers a useful way of conceptualizing the relationship between certain "contingency" variables and organization structure. In particular, we see the proliferation of research into knowledge management as an opportunity to revisit the idea that certain aspects of a firm's technology might influence its structure (Woodward 1965). Below we offer a brief review of this technology-specific literature, before moving into a detailed discussion of the ways that a firm's knowledge base might influence its choice of organization structure. In this section we also consider how a configurational approach might provide additional insights.

Technology as a Contingency Variable. There is a long tradition of research on technology in organizations. Beginning with Woodward's (1965) study of manufacturing firms in England, and with important contributions from Perrow (1967), Thompson (1967), Hickson et al. (1969), Khandwalla (1974), and Blau et al. (1976), this body of research sought to identify relationships between the critical dimensions of technology and various aspects of organization structure and design. Three key issues emerge from this body of literature. First, it is no simple matter to define the relevant dimensions of technology.[1] Woodward (1965) focused on complexity (unit production, mass production, process production); Perrow (1967) identified task variability and problem analyzability as the key dimensions; and Thompson (1967) developed a classification whereby technologies could be long linked, mediating, or intensive. In an attempt at a synthesis, Gerwin (1979) argued that the common element of all three studies was routineness, and that routineness ceteris paribus was associated with low complexity, formalization, and centralization.

Second, there has been considerable debate over the appropriate level of analysis for measuring technology. Woodward and other early studies (Harvey 1968, Hickson et al. 1969, Zwerman 1970) measured technology at the firm level, but Perrow (1967) and many subsequent studies focused at the level of the task or unit (e.g., Grimes and Klein 1973, Van de Ven et al. 1974). Broadly speaking, it was shown that "Technology had its strongest effect on structures in closest proximity to it" (Jackson and Morgan 1982, p. 199), i.e. at the task or unit level.

Third, and related to the second point, the actual relationship between technology and structure has been challenged. The Aston Studies (e.g., Pugh et al. 1969, Hickson et al. 1969) showed that the relationship between technology and structure disappeared after controlling for size. Comstock and Scott (1977) made the same observation at the firm level, but saw a significant relationship at the unit level. Relatedly, there have also been concerns raised about how independent measures of technology and structure are. As observed by Reimann (1980, p. 62), "researchers who have defined technology in terms of environmental inputs and outputs have come up with considerably more consistent findings than researchers . . . who focused on the transformation process itself." In other words, separating out the nature of technological transformation from the organizational system used to achieve the transformation is not easy.

This body of research has not developed much since the early 1980s, a fact that can be attributed in part to the decline in interest in contingency theory as a whole, and in part to the rather ambiguous set of findings described above. But the emerging body of literature in knowledge management represents an interesting development, because technology and knowledge are related constructs.[2] In the next section, we consider the various approaches to measuring knowledge before getting into an analysis of the impact of knowledge characteristics on organization structure.

Knowledge as a Contingency Variable. Knowledge is an elusive concept that has been classified and defined in a variety of ways (see, e.g., Hedlund 1994, Huber 1991, Nonaka and Takeuchi 1995, Spender 1996). We start with the basic distinction between *information* and *know-how* (Kogut and Zander 1992). Information is "knowledge which can be transmitted without loss of integrity once the syntactical rules for deciphering it are known." Know-how is "the accumulated practical skill or expertise that allows one to do something smoothly and efficiently" (Kogut and Zander 1992, p. 386; von Hippel 1988). While these definitions work well at the individual level of analysis, their relevance to this paper is as firm-level constructs. Thus, the focus is on the firm's *knowledge assets*, which includes technology, human capital, patents, brands, and organizational routines. Knowledge assets can be seen as consisting of both information and know-how, though some are relatively high in information (e.g., patents) and others are relatively high in know-how (e.g., organizational routines).

In a landmark study, Winter (1987) took the information vs. know-how distinction further by suggesting that knowledge assets could be understood in terms of four key dimensions: (a) tacit—articulate, (b) observable in use—not observable, (c) complex—simple, and (d) element in a system—independent. These dimensions, he argued, are directly related to *the ease of transfer of the knowledge asset* in question—some types of knowledge are tacit, hard to observe, complex and system dependent, and are thus very hard to transfer; other types are easy to articulate, observable in use, simple and system independent, and are very easy to transfer.

As noted above, technology can usefully be seen as an important category of knowledge assets. However, we see Winter's dimensions of knowledge as a significant departure from the dimensions of technology used previously, for two reasons. First, they are very "relevant" measures for relating type of knowledge to firm competitiveness because they address the question of ease of voluntary and involuntary transfer. Second, because they are concerned with the intrinsic nature of knowledge assets, rather than how those knowledge assets are used, it should be possible to avoid the problem mentioned above of a lack of discriminant validity between measures of "technology" and "structure." It is also worth noting that Winter's dimensions have already been operationalized by Zander and Kogut (1995), thereby making our empirical analysis more straightforward.

In this paper we focus on two dimensions of knowledge—observability and system embeddedness (system dependence in Winter's terms). *Observability in use* is defined by Winter (1987, p. 172) as "the extent of disclosure of underlying knowledge that is necessitated by use of the knowledge." Zander (1991, p. 147) defines *observability* rather differently, as "how easy it is to understand the activity by looking at and examining different aspects of the process or final product." The difference between the two definitions is that Zander is more concerned with active attempts to imitate a technology or process by competitors (including such things as plant tours and reverse engineering), whereas Winter sees observability as a more passive activity undertaken by the consumer or user of the product. Because we are using Zander and Kogut's (1995) measures, it is more appropriate to adopt their definition.

System embeddedness refers to the extent to which the knowledge in question is a function of the system or context in which it is embedded. Embeddedness consists of many interacting components: the level of interdependence between individuals and teams working on related activities, the level of experience of those individuals, the inability to divide up or modularize a given activity, and the site specificity of an activity. We use the term system embeddedness rather than Winter's (1987) system dependence because it hints at the importance of the social system in which the knowledge is "embedded" (Bijker et al. 1987, Granovetter 1985, Grabher 1993, Latour 1987).

We will shortly get into a more detailed discussion of knowledge observability and system embeddedness. However, before doing that it is important to be more specific about the empirical context of this study, which is the dispersed R&D organizations of Swedish multinational firms.

Empirical Context of Study

The research was conducted in the R&D organizations of 15 large Swedish multinational firms. The level of analysis was the individual R&D unit, and the key respondents to the questionnaire were the top managers of the R&D units. They answered questions about their perceptions of the characteristics of knowledge and about the organization structure.

In this context, the appropriate measures of organization structure were deemed to be the *autonomy of the R&D unit* and the level of *interunit integration*. Autonomy is the extent to which the R&D unit is able to make strategic decisions without the involvement of corporate headquarters. Interunit integration refers to the state of collaboration among units, and the techniques used to achieve this collaboration. These two dimensions parallel Lawrence and Lorsch's (1967) measures of differentiation and integration. They are also very relevant in the international R&D literature. See, for example, the concept of the "integrated network" of R&D units described in Håkanson and Zander (1986), and the importance of autonomy and integration in other studies (Behrman and Fisher 1980, Pearce 1989, Ronstadt 1977).

This empirical setting was selected for two reasons. First, the focus of the research on knowledge as a contingency variable meant that a knowledge-intensive context such as R&D was appropriate. Second, we wanted a setting in which the organization design issue was important, so that there would be sufficient variance in the dependent variables. If we had focused on single-location R&D laboratories, there was a risk that the differences in organization design would not be that great. By looking at *international* R&D organizations, in contrast, we were confident that significantly different organization designs would be seen. As one example of this logic, interunit collaboration is extremely expensive in an international setting, so it will not occur without a conscious policy of encouragement.

The R&D unit level of analysis creates some conceptual difficulties for contingency theory. Contingency theory research has been done in two basic ways. One way has been to take the firm in its entirety as the unit of analysis, and look at the interaction between various facets of its industry, strategy, and organization structure. In the multinational domain the contingency studies of Daniels et al. (1984), Egelhoff (1982), and Stopford and Wells (1972) are of this type. The other approach—the one used here—is to look at the same phenomenon from the level of the subsidiary company or R&D unit. Here, the contingency argument is somewhat different. Rather than modeling the multinational corporation as a single firm, it is modeled as an interorganizational network (Ghoshal and Bartlett 1990) of semi-independent subsidiary units, each of which faces its own unique local environment. Because each local environment is different, it is necessary to define different strategic roles for subsidiaries and to structure their relationships with the rest of the corporation accordingly (Ghoshal 1986). Using this approach, all measurement takes place at the level of the subsidiary or R&D unit. Studies in this genre have looked at many subsidiaries in a small number of firms (Ghoshal and Nohria 1989), or more typically a cross-section of units from a single country (e.g., Jarillo and Martinez 1990, White and Poynter 1984).

The difference between these two approaches is important. The underlying logic of contingency theory is that the selection of an appropriate organization structure (to "fit" the environment, strategy, or knowledge) will lead to higher performance, and consequently that a failure to select the right structure will end in underperformance. In the former case, managers are responsible for defining a structure which is then accepted or rejected in the marketplace. In the latter case, however, corporate managers are responsible for both defining the structure of their subsidiary units *and* for making judgements about those units' successes or failures. This dual role prevents an objective (market-tested) evaluation of fit, and thus increases the likelihood that some poorly fitting subsidiaries will survive.[3] The point here is not to deny the validity of contingency theory at the subsidiary level of analysis (see, for example, the strong performance test in Ghoshal and Nohria 1989), but just to acknowledge that it works through an internal-selection environment rather than an external one (Burgelman 1991, Galunic and Eisenhardt 1996). We will return to this issue later.

Hypothesis Development

We are now in a position to develop specific hypotheses for empirical testing. Four hypotheses are put forward relating the dimensions of knowledge to organization structure. We also put forward a number of control variables concerned with the roles of the R&D units; size;

age; and industry, firm and country effects. Finally, we also examine the "fit" hypothesis by specifying the interaction between the dimensions of knowledge and organization structure as a predictor of knowledge transfer. Figure 1 provides a graphical summary of the hypotheses.

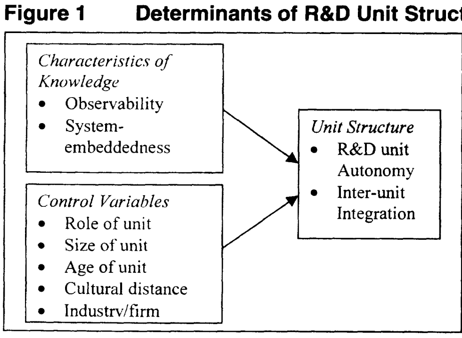
Observability of Knowledge. The core argument here, building on Winter (1987) and Zander and Kogut (1995), is that the more observable the knowledge is—either to another employee in the same firm or to a competitor—the more easily it is transferred or disseminated to another location. Stated slightly differently, knowledge is increasingly seen as a *sticky* asset, meaning that it flows between locations with some difficulty (Arrow 1971, Szulanski 1996, von Hippel 1994). Certain characteristics, however, make knowledge less sticky, and observability is one such characteristic.

What are the implications of this for organization structure? If we assume that the global R&D organization would like access to the pockets of knowledge developed in individual R&D units, the organization structure chosen should reflect the difficulty with which knowledge is transferred. When observability is low, knowledge transfer requires a process of learning by doing which typically involves considerable face-to-face interaction between the two parties to the transfer. When observability is high, knowledge transfer is achieved more quickly, so the level of interpersonal interaction between R&D units can be much lower. This leads to the first hypothesis.

HYPOTHESIS 1. *The more observable the R&D unit's knowledge, the lower the level of interunit integration.*

A similar logic can be put forward concerning the level of R&D unit autonomy. Autonomy is a double-edged sword in an R&D organization. Units are given autonomy to provide them with the necessary degrees of freedom to be creative and to respond to technological and market opportunities as they arise. But too much autonomy can result in a duplication of effort, a lack of interunit learning, and a lack of coherence to the overall R&D strategy.

Figure 1 Determinants of R&D Unit Structure



When knowledge observability is low, it will not flow easily between locations, so autonomy is likely to be curtailed. However, when knowledge observability is high it flows far more easily, and as a result it is possible for individual R&D units to be more autonomous and still achieve knowledge transfers.

HYPOTHESIS 2. *The more observable the R&D unit's knowledge, the higher the level of unit autonomy.*

System Embeddedness

To make sense of the system embeddedness of knowledge, it is useful to draw on a number of related literatures. There is a well-established body of literature concerned with the sociology of technology, which in essence argues that technological change can only be understood through an analysis of the social context in which it occurs (Bijker et al. 1987, Knorr-Cetina 1981, Latour 1987, MacKenzie 1995). Rather than focus on the technical *content* of knowledge, this literature emphasizes the social *processes* through which knowledge is produced, shared, and institutionalized, the implication being that all knowledge is—to a greater or lesser degree—a function of the social system in which it is embedded.

One specific line of research that builds on the sociology of technology is concerned with the situated nature of learning (Brown and Duguid 1991, Kogut and Zander 1992, Lave and Wenger 1991, Polanyi 1962). This line of thinking "directs attention to the particulars of what problem solvers actually do as they investigate problems and correct errors, and how they use the resources available to them in the process" (Tyre and von Hippel 1997, p. 71). In essence, it argues that the social *and* physical context in which a person works affects their actions and their learning. The impact of social context on learning has been the subject of detailed academic research (e.g., Brown and Duguid 1991, Orr 1990), but within this particular field of inquiry the impact of physical context on learning has received relatively little attention (Tyre and von Hippel 1997).[4]

The system embeddedness construct suggests that some knowledge is much more sensitive to its social and physical context than other knowledge. Using a couple of examples from the interviews that were conducted during this research, Ericsson's software development is undertaken according to well-established procedures that are relatively easily replicated in different settings. Sensitivity to physical location and social context is therefore low. Alfa Laval's R&D in milking machines and separators, in contrast, has always been undertaken in specialized locations. These locations have dedicated physical infrastructure, all relevant functional activities (research, development, engineering, manufacturing, suppliers, customers, etc.) nearby, and around a century of experience in the relevant technology (which has not changed that much over the years). The knowledge underlying these Alfa Laval operations, we argue, is very sensitive to location, and would be very costly to move. However, it is important to be clear that system embeddedness is *not* another way of talking about tacit knowledge. Indeed, as shown in Table 3, the correlation between observability (which we see as close to the articulability-tacit dimension of knowledge) and system embeddedness is 0.06, i.e., they are essentially orthogonal.

The implication of this discussion is that physical location *and* the social context that exists in that location matter a great deal for certain types of knowledge. As the Alfa Laval example suggests, some bodies of knowledge emerge over time in a process of coevolution with the location in which they are embedded. Because of the causal ambiguity and complexity of the knowledge in question, it becomes very risky to transfer it. As a result, firms prefer to develop the knowledge in situ, using an "if it ain't broke, don't fix it" type of argument. By contrast, other bodies of knowledge appear to be relatively context neutral, and are therefore adapted or applied in multiple different locations.

In terms of specific hypotheses, R&D unit autonomy should, according to this logic, be positively correlated with system embeddedness. Taking the perspective of corporate R&D management, if the firm's knowledge is highly system embedded it is best developed through a small number of centres of excellence, each based on a history of success within a given technological area and each with a relatively high level of autonomy to develop that knowledge as it sees fit. By contrast, if the knowledge is more context neutral, R&D work can be moved between locations when necessary, and R&D units can be enlarged or shrunk according to demand. However, for this approach to work individual units must work to certain common standards or procedures, i.e., have relatively low autonomy.

This logic also suggests that system embeddedness will have a negative correlation with interunit integration. When system embeddedness is high, R&D units will typically have all the necessary technologies on-site and will therefore develop in "splendid isolation," with relatively weak links to the other R&D units. When system embeddedness is low, however, fairly close interunit integration will be necessary to ensure that the overlaps and interdependencies between activities are managed effectively. Thus:

HYPOTHESIS 3. *The more system embedded the R&D unit's knowledge, the lower the level of interunit integration.*

HYPOTHESIS 4. *The more system embedded the R&D unit's knowledge, the higher the level of unit autonomy.*

While these hypotheses are expressed in correlational terms, it is worth speculating on the likely direction of causality between the characteristics of knowledge and organization structure. As developed, the causal logic flows from system embeddedness towards autonomy and integration. The reasoning behind this is that we see system embeddedness as a fundamental characteristic of knowledge, and one which the organization should adapt itself to. However, we recognize that the reverse causality will also transpire, so that, for example, a highly autonomous unit may develop its R&D knowledge in isolation, and over time its knowledge becomes site specific, specialized, and de facto system embedded (cf. the Not Invented Here syndrome, Katz and Allen 1982).

Characteristics of Knowledge and Knowledge Transfer

The final set of hypotheses suggest that the interaction between the dimensions of knowledge and organization structure variables will be associated with knowledge transfer. This is based on the traditional contingency logic that "fit" between variables should lead to superior performance. Of course, we do need to acknowledge that fit within the firm is achieved through parent-company intervention rather than market survival, which is likely to attenuate the strength of the finding, but nevertheless we would expect to see some sort of relationship.

Two questions arise here. First, what is the appropriate measure of performance? And second, what is the appropriate way of measuring fit? Taking the performance question first, our preference was to focus on a rather narrower concept of performance than would normally be the case, in keeping with the specific nature of the relationships being tested. We therefore opted to focus on *knowledge transfer* between the R&D unit and other parts of the organization. If we see the firm's knowledge base as a key resource, then knowledge transfer can be seen as a necessary (though not sufficient) condition for the attainment of competitive advantage. Moreover, this focus is also consistent with Winter's (1987) initial formulation of the dimensions of knowledge assets in relation to their ease of transfer within the firm. Finally, while a traditional performance measure might be desirable, in the context of an R&D organization it is not obvious what such a measure would be because R&D units have such different roles.

In terms of the measurement of fit, there are a number of approaches commonly used though each has its own limitations (Donaldson 1995, Drazin and Van de Ven 1985, Schoonhoven 1981). Our approach in this paper is to construct an interaction term between the knowledge contingency and the organization structure variable and then to hypothesise that the interaction will be positively related to knowledge transfer (Schoonhoven 1981). This approach is asymmetrical, so that (for example) increasing interunit integration will lead to greater knowledge transfer when system embeddedness is low, but *decreasing* interunit integration when system embeddedness is *high* will not. This is consistent with the logic developed earlier. Four hypotheses can therefore be specified. Using the wording recommended by Schoonhoven (1981) they are stated as follows:

HYPOTHESIS 5A. *The less system embedded the R&D unit's knowledge, the greater the impact of interunit integration on knowledge transfer.*

HYPOTHESIS 5B. *The less observable the R&D unit's knowledge, the greater the impact of interunit integration on knowledge transfer.*

HYPOTHESIS 5C. *The more system embedded the R&D unit's knowledge, the greater the impact of R&D unit autonomy on knowledge transfer.*

HYPOTHESIS 5D. *The more observable the R&D unit's knowledge, the greater the impact of R&D unit autonomy on knowledge transfer.*

Control Variables. To avoid picking up spurious relationships between knowledge and organization structure it is important to control for other likely predictors of R&D unit autonomy and interunit integration. Drawing specifically from the international R&D literature, the appropriate control variables were identified as follows.

R&D Unit "Role." Several studies have shown that R&D units take on very different roles within the corporate system—such as Ronstadt's (1977) global technology units, corporate technology units, and technology transfer units, and Kuemmerle's (1998) home-base exploiting and home-based augmenting units. Here we measured two important aspects of the R&D unit's role—the extent to which it is focused on local rather than international R&D issues (Nobel and Birkinshaw 1998), and the relative focus on adaptation and improvement work rather than pure research and development (Håkanson and Nobel 1993).

Industry and Firm Effects. Industry structure varies widely from case to case, and with it many important elements of the conduct of firms, the type of technology being developed, the intellectual property regime, and so on. It is therefore important to control for the industry in analyses of this sort. As observed below, however, the nature of the sample (typically one firm per industry) is such that firm-level dummies end up also proxying for industry-level dummies.

Country Effects. Because of our focus on international R&D organizations, the specific location potentially matters a great deal especially with regard to R&D unit autonomy and the potential for interunit integration (Håkanson and Zander 1986). Rather than specifying country dummies we instead employed a measure of cultural distance (Kogut and Singh 1988), because we felt that issues of autonomy and integration were at least as much tied up in cultural differences as in pure geographical distance.

Unit Size. Organization size has long been recognized as an important factor in contingency research (Hickson et al. 1969) and indeed it has been identified as one of the key contingencies in organizational design (Baligh et al. 1996). We therefore control for the size of the R&D unit, measured in terms of the number of employees.

Unit Age. Finally, we control for the age of the R&D unit because the level of system embeddedness of the knowledge assets is likely to change significantly over time.

Research Methodology

The propositions were tested using data from a questionnaire mailed to all the R&D unit managers in 15 large Swedish multinational firms. In a 50-interview exploratory study of five Swedish multinationals, we discussed with R&D managers various aspects of technology transfer, interunit communication, network management, and unit roles to ensure that we could put together a valid questionnaire. In these interviews we also determined that the R&D unit manager was the key respondent, in that no one else at the head office or in the subsidiary unit was knowledgeable about both the activities of the R&D unit *and* its relationships with other entities.

Questionnaire Development and Sample Selection

We wrote an initial draft of the questionnaire using a combination of scales taken from prior studies and original questions based on issues uncovered in the exploratory study. We then assembled a reference group consisting of three corporate R&D managers from major Swedish MNCs, representatives of the royal academy of engineering and the Swedish agency for technical development (NUTEK), and several academics with expertise in this area. The group met twice to discuss the face validity of the questions and any modifications or enhancements that they felt were appropriate. This process resulted in several substantive changes to the questionnaire.

The sampling frame for the questionnaire survey was the population of R&D laboratories in the 20 largest Swedish MNCs. These MNCs account for approximately 75% of all industrial R&D undertaken in Sweden (Håkanson and Nobel 1993). Of these 20 MNCs, 15 agreed to participate in the study. Discussions with corporate R&D management led to the identification of 210 R&D units. The R&D manager in charge of each unit was mailed a copy of the questionnaire with a cover letter indicating the support of the parent company. Follow-up telephone calls and a second mailing to nonresponders yielded a total of 110 usable responses, of which 34 were Swedish units and 76 foreign. We examined the nonrespondents in terms of their location and their parent firm, but no major problems were uncovered. Overall though, the sample is slightly biased towards certain firms (Alfa Laval, Tetra Pak) and against others (Sandvik, SKF), which is a reflection of the interest shown in the research by the corporate management in question. The breakdown of responding units by company and host country is presented in Table 1.

A separate questionnaire was mailed to a sample of divisional and corporate R&D managers. This questionnaire was primarily for general information, but it included a few questions that were identical to those answered by R&D unit managers. We were able to use these common questions to assess interrater reliability, which was acceptable.[5]

Table 1 Breakdown of Responding Units by Company and Country

	S	US	D	GB	B	NT	I	Other Europe	Other Asia, Americas	Total
Aga		1	1							2
Alfa Laval	6	4	1	2	1	1	1		1	17
Atlas Copco	1		1		4					6
Ericsson	8	1	1	2		1	1	4	4	22
Esab		1		1		1				3
ABB	9	2	5					5	2	23
Nobel				1						1
Kabi	2	1								3
Saab Scania	1	1				1			3	6
Sandvik				1						1
SKF	1		1			1	1			4
Stora			1							1
Tetra Pak	2		2	1			1	1	2	9
Trelleborg	2	1			1					4
Volvo	2	3		2					1	8
Total	34	15	13	10	6	5	4	10	13	110

Key. S = Sweden, US = United States, D = Germany, GB = Great Britain, B = Belgium, NT = Netherlands, I = Italy. Other Europe = Norway, Denmark, Finland, Ireland, Switzerland, France, Spain. Other America, Asia = Canada, Mexico, Brazil, Argentina, Singapore, Japan, Australia, India.

Construct Operationalization

All constructs were measured using existing scales where possible, and using carefully tailored questions where not. In particular, the central constructs of observability and system embeddedness were taken from Zander and Kogut (1995). Table 2 provides a summary of the constructs, the source of the measurement scale, and the reliability of the scale. Appendix 1 provides exact wording of items.

Findings and Discussion

Descriptive statistics and zero-order correlations for the variables are shown in Table 3. The hypotheses were tested using OLS regression.[6] Table 4 provides the results of the tests for Hypotheses 1 to 4. In order to estimate the additional variance explained by the knowledge variables over and above that explained by the controls, we used a two-block model, entering the control variables in Block 1 and the two knowledge variables in Block 2. Model 1 has interunit integration as the dependent variable, Model 2 has R&D unit autonomy as the dependent variable.

In Model 1, system embeddedness emerges as the strongest predictor of interunit integration ($p < 0.001$), thereby providing strong support for Hypothesis 3. Observability is also significant, but only at $p < 0.05$, providing moderate support for Hypothesis 1. In other words, the more system embedded and observable the knowledge, the *lower* the level of interunit integration. Of the control variables, only the Alfa Laval dummy variable is significant. Overall, the adjusted R-square for the model is 0.292 ($F = 4.42$), and the significance of the change in F when the knowledge variables are entered is $p = 0.001$.

In Model 2, system embeddedness is a strong predictor variable ($p = 0.004$) of R&D unit autonomy, providing support for Hypothesis 4—that the more system embedded the knowledge, the greater the autonomy of the R&D unit. However, observability does not come out significant, so Hypothesis 2 is not supported. Of the control variables, Alfa Laval is again significant, as is the local focus of the R&D unit. In other words, R&D units with a greater focus on local R&D, and those belonging to Alfa Laval, tend to be more autonomous. Overall, the adjusted R-square for the model is slightly weaker than in Model 1 ($0.213, F = 3.31$), but again the change in the F statistic when the knowledge variables are added is highly significant ($p = 0.007$).

Table 2 Summary of Constructs

Construct	Scale Measurement and Reliability (Cronbach's Alpha)	Source of Scale
R&D Unit Autonomy	6 items (0.86)	Hedlund (1981)
Interunit Integration	3 items (0.75)	Adapted from Lawrence and Lorsch (1967)
Observability of Knowledge	3 items (0.86)	Zander and Kogut (1995)
System Embeddedness of Knowledge	6 items (0.69)	Zander and Kogut (1995)
Knowledge Transfer	2 items (0.86)	—
Research Focus of R&D Unit	Single question	—
Local Focus of R&D Unit	Single question	—
Cultural Distance	Secondary data	Kogut and Singh (1988)
Age of R&D Unit	Single question	—
Unit Size	Single question	—

There is one caveat to these findings. While dummy variables capture the difference between the single firm and the sample average, they do not guard against the existence of a joint ABB/Alfa Laval/Ericsson effect. To investigate the possibility of such an effect, we reran the analysis without the R&D units from these companies, i.e., with the remaining 48 units. The results of this analysis are also reported in Table 4. It shows that observability is still a significant predictor of interunit integration, but that system embeddedness is no longer significant in either model—which suggests that to a large degree the different levels of system embeddedness in ABB, Alfa Laval, and Ericsson are what emerge in the full-sample analysis. This underlines that the findings from the study should be seen as exploratory, and not readily generalizable to other contexts.

Hypotheses 5a–5d predicted that the interaction between knowledge contingencies and organization structure would be associated with the transfer of knowledge from the R&D unit to the rest of the multinational firm. In order to test these hypotheses we first created four interaction terms, which are simply the product of the knowledge and structure variables (integration × (reversed)[7] observability, integration × (reversed)system-embeddedness, autonomy × observability, autonomy × system-embeddedness). Then we ran two regression models, Model 1 focusing on interunit integration and its interaction with knowledge, Model 2 focusing on unit autonomy and the interaction with knowledge. Again, the variables were entered in two blocks, with the second block consisting solely of the two interaction terms. The results are listed in Table 5.

Of the four "fit" hypotheses, 5a was strongly supported and 5b–5d were not. What the significant finding suggests, in essence, is that the high performers in terms of knowledge transfer were those units with high levels of integration with other units *coupled with* a low level of system-embedded knowledge. This confirms that there is a link between the dimensions of knowledge and the *transferability* of knowledge, as argued by Winter (1987). However, caution is required in interpreting this result because the importance of knowledge transfer is likely to vary between units, and knowledge transfer is to some degree confounded with interunit integration and R&D unit autonomy. For example, in cases where system embeddedness is high, it may well be that knowledge transfer is not even attempted.

Dimensions of Knowledge

The findings provide support for Hypotheses 1, 2, and 4, confirming that the characteristics of knowledge are important predictors of structure in international R&D organizations. But it is worth considering the nature of the relationships in greater detail, albeit in a rather speculative fashion. Figure 2 plots the observability of knowledge against the system embeddedness of knowledge. It also indicates the commensurate organization structure arrangements that emerge as a result of the statistical analysis. The basic picture that emerges is of "isolated" R&D units in the northeast quadrant that are more autonomous and less integrated, and "integrated" R&D units in the southwest quadrant that are less autonomous and more integrated. In terms of making sense of the other boxes in the matrix, it is useful to recall Winter's (1987) argument that ease of transfer of knowledge is a double-edged sword—the knowledge can be easily transferred inside the firm, but it can also be easily imitated. This argument would suggest that the R&D units in the southeast corner of the matrix have *opaque* knowledge—they cannot be fully understood even by the firm that owns them, let alone their competitors. At the other extreme, the R&D units in the northwest corner have *transparent*

Table 3 Pearson Correlation Coefficents for all Constructs

	Mean	SD	2	3	4	5	6	7	8	9	10	11	12	13
1. System Embeddedness	4.54	1.06	0.06	−0.27**	0.38**	−0.07	0.15	−0.09	0.03	−0.00	−0.12	−0.01	−0.26**	0.21*
2. Observability of Knowledge	2.96	1.34		−0.25*	0.16	−0.16	−0.15	−0.10	0.06	0.04	−0.05	0.12	−0.30**	−0.02
3. Interunit Integration	3.87	1.00			−0.39**	0.28**	0.23*	−0.09	0.23*	−0.01	−0.08	−0.39**	0.26**	0.04
4. R&D Unit Autonomy	3.17	1.13				−0.10	0.07	0.07	0.03	0.23*	0.07	0.31**	−0.19*	0.11
5. Knowledge Transfer	5.24	13.24					0.15	−0.16	0.07	−0.07	−0.10	−0.10	0.15	−0.02
6. Size of R&D Unit	1293	2458						−0.03	0.04	0.04	0.07	−0.16	0.12	0.15
7. Age of R&D Unit	1971	25							0.04	0.07	0.36**	0.20*	−0.01	−0.07
8. Research Focus of R&D Unit	48.8	25.5								−0.32**	−0.24*	0.01	0.08	−0.12
9. Local Focus of R&D Unit	26.6	33.7									0.50**	−0.01	−0.06	−0.00
10. Cultural Distance	2.84	1.57										0.03	−0.01	−0.18
11. Alfa Laval Company	0.15	0.36											−0.21*	−0.22*
12. Ericsson Company	0.20	0.40												−0.26**
13. ABB Company	0.21	0.41												

*** <0.001; ** <0.01; * <0.05 (two-tailed tests)

Table 4 Predictors of Interunit Integration and R&D Unit Autonomy

	Model 1 Interunit Integration		Model 2 R&D Unit Autonomy		Subsample (n = 48) Excluding all ABB, Alfa Laval, Ericsson	
	Entered in Block 1	*Entered in Block 2*	*Entered in Block 1*	*Entered in Block 2*	Interunit Integration	R&D Unit Autonomy
Size of R&D Unit	0.141	0.165	0.092	0.069	0.482*	−0.08
Age of R&D Unit	−0.024	−0.034	−0.169	0.000	0.109	0.006
Research Focus of R&D Unit	0.214†	0.224*	0.198†	0.177	0.400*	0.031
Local Focus of R&D Unit	0.106	0.158	0.297*	0.248*	0.325	0.280
Cultural Distance	−0.074	−0.129	0.018	0.048	−0.245	−0.045
Alfa Laval Company	−0.278*	−0.301**	0.368**	0.374**	–	–
Ericsson Company	0.165	0.028	−0.026	0.085	–	–
ABB Company	−0.001	−0.011	0.184	0.182	–	–
System Embeddedness of Knowledge		−0.322**		0.300**	0.004	0.083
Observability of Knowledge		−0.192*		0.127	−0.358*	0.067
Adjusted R-Squared	0.169	0.292	0.125	0.213	0.150	−0.41
F Statistic (sig.)	3.11**	4.42***	2.516*	3.307**	1.89	0.37
Change in F (sig.)		7.52**		5.34**		

Standardized beta values reported
*** <0.001; ** <0.01; * <0.05; † <0.10 (two-tailed tests)

knowledge—they are easily observed in use, and they are context neutral. Such knowledge is not at all sticky, and as such it is unlikely to form an important part of the firm's competitive advantage.

This argument is speculative, but it is based on the data collected in this study and it is also consistent with the anecdotal evidence we have collected in such companies as Ericsson and Alfa Laval. The key insight, we believe, is that most of the knowledge management literature to date has focused *only* on the vertical dimension of the matrix—with observability as a crude proxy for the widely used distinction between tacit and articulate knowledge. Thus, for example, the idea that knowledge can be managed in a "virtual" manner through IT systems

Table 5 Predictors of Knowledge Transfer

	Model 1 Interunit Integration, Knowledge, and Interactions		Model 2 Unit Autonomy, Knowledge, and Interactions	
	Entered in Block 1	*Entered in Block 2*	*Entered in Block 1*	*Entered in Block 2*
Size of R&D Unit	0.000	0.026	0.025	0.042
Age of R&D Unit	0.027	0.039	0.014	0.002
Research Focus of R&D Unit	0.052	0.023	0.107	0.102
Local Focus of R&D Unit	−0.012	0.002	0.036	0.043
Cultural Distance	0.008	0.014	0.025	0.021
Alfa Laval Company	−0.066	−0.037	−0.070	−0.098
Ericsson Company	0.246*	0.138	0.264*	0.234†
ABB Company	0.000	−0.043	0.019	−0.005
System Embeddedness of Knowledge	−0.239*	0.794†	−0.249*	−0.663†
Observability of Knowledge	−0.145	0.417	−0.143	−0.193
Interunit Integration	0.124	−1.29*		
Unit Autonomy			−0.088	0.119
Interaction Terms				
Integration x System Embeddedness		1.605*		
Integration x Observability		.852		
Autonomy x System Embeddedness				.873
Autonomy × Observability				0.119
R-Squared	0.281	0.363	0.275	0.293
Adjusted R-Squared	0.171	0.244	0.167	0.165
F Statistic (sig.)	2.56**	3.06**	2.55**	2.29*
Change in F (sig.)		4.49*		0.93

Standardized Beta values reported
*** <0.001; ** <0.01; * <0.05; † <0.10 (two-tailed tests)

has tended to focus on the challenges of codifying tacit knowledge. Much less consideration has been given to the question of how knowledge can be "uprooted" from the system in which it is embedded (Brown and Duguid 1999, Tyre and von Hippel 1997). These are clearly important issues for further research.

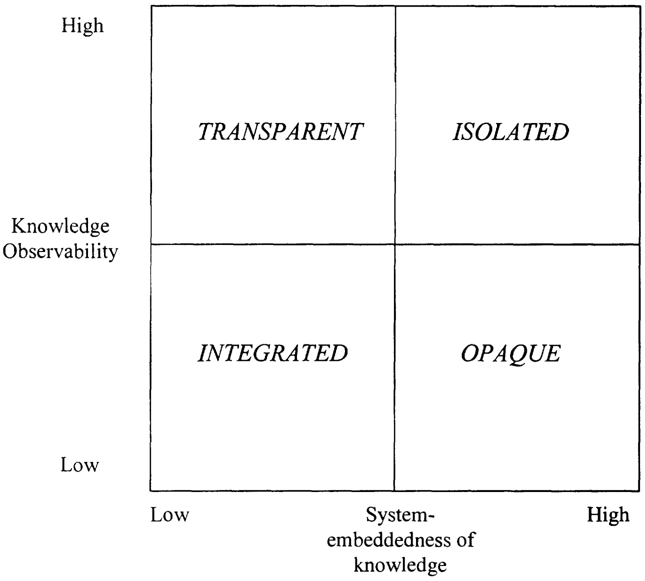
Towards a Configurational Approach

Taken together, the results provide strong support for the basic premise of the paper that characteristics of knowledge are important predictors of organization structure. However, the results also indicate two problems that deserve further scrutiny. One is the weak performance test, which could be attributed either to a poorly chosen performance measure, or to equifinality, i.e., the idea that different structures can achieve very similar results. The second problem is the significant correlation between R&D unit autonomy and interunit integration ($r = -0.39$), which suggests that as we think about further research in this area a configurational framing (rather than a pure contingency framing) may be more appropriate (Meyer et al. 1993).

A recent paper by Gresov and Drazin (1997) provides some insights into how these problems can be resolved. They argue that organizations face very different design scenarios depending on (a) the degree of conflict in the functional demands placed on the organization, and (b) the latitude of structural options the organization can select. Where there is no conflict in what the organization should be delivering and structural options are tightly constrained, a "one best way" of organizing should emerge. However, in all other situations with conflict in functional demands, unconstrained structural options, or both, we would expect to see some form of equifinality, in which different configurations of structure and context are equally high performing.

If we apply this thinking to the current study, some interesting insights emerge. We would argue that the *functional demands* on an R&D unit are complex and

Figure 2 **Observability vs. System Embeddedness—Characteristics of Knowledge in Four Different Types of R&D Units**



multidimensional-knowledge transfer is an important objective, but so are such things as innovativeness, productivity, and quality. In terms of the *latitude of structural options*, we would argue that these are relatively unconstrained, in that we have evidence of several combinations of autonomy and integration coexisting. Taken together, this suggests a situation of *configurational equifinality* (Gresov and Drazin 1997, p. 409), which means that two or more distinct configurations or "ideal types" should be identifiable (Meyer et al. 1993). For example, an "isolated" R&D unit might be characterized by high observability, high system embeddedness, high autonomy and low interunit integration, and an "integrated" R&D unit by the exact opposite set of characteristics.

While this seems to be a promising line of thinking, it is important to underline that we are not yet in a position to develop it in a rigorous way, or to test it empirically. The biggest problem is that configurational analysis requires the existence of theoretically derived "ideal types" such as Miles and Snow's (1978) defender, prospector, analyzer and reactor types (Van de Ven and Drazin 1985, Doty et al. 1993). Currently, no such theory exists in the knowledge management literature. The second problem is that we need a better specification of the functional demands on an R&D unit, i.e., what it is trying to achieve. The current study was framed only in terms of the demand for knowledge transfer, which explains the weak support for Hypotheses 5a–5d but does not do justice to the full scope of demands on an R&D unit. Finally, we do not have a particularly good feel for how structural options in R&D units are constrained. Our sense is that R&D unit managers have considerable degrees of freedom in selecting the appropriate levels of autonomy and integration, and that their choices are affected by their understanding of the unit's knowledge assets. But there also appears to be a significant firm-level effect, which acts as a constraint on the latitude afforded to R&D unit managers.

Conclusions

This study sought to make contributions to two bodies of thinking: contingency theory and knowledge management. In terms of contingency theory, we argued and found strong support for the importance of certain dimensions of knowledge as contingency variables. Of course, the context of the study—international R&D organizations—was very specific, and carefully chosen to illuminate the relationships under investigation, so we should be careful not to generalize too much. Nevertheless, the findings are persuasive, and they suggest that it is worth examining the role of knowledge contingencies in a variety of different settings, and with different dimensions of knowledge. We also highlighted the possibility that some form of configuration analysis might be appropriate in future research in this area. A straightforward contingency framing was a useful first step, but in reviewing the results, its limitations became apparent, so some suggestions were made as to how a configurational approach might be developed.

In terms of knowledge management, the key contribution was to identify and examine the implications of *system embeddedness* as an important dimension of knowledge. While system dependence has been acknowledged before, it has been typically been treated in a similar way to such dimensions as articulability and observability (Winter 1987). In this study we showed that system embeddedness is orthogonal to observability, and that it is an important predictor of organization structure. We also speculated at some of the possible implications of modeling a firm's knowledge on the basis of these two dimensions.

A couple of limitations in this study should first be noted. First, we used attitudinal data from a single respondent (the R&D unit manager), with some validity checks at the HQ level. This causes limitations in two ways. First, one can argue that the R&D unit manager is biased or does not provide an objective response (though in this case there is no better respondent). Second, it can result in common-method bias (which is a more significant problem). What would be valuable, though difficult to collect, would be secondary data about such things as unit autonomy, interunit integration, and knowledge transfer. The measures of knowledge, interestingly, can probably not be collected in any other way because in such things perception really is reality. A second limitation is that we were only able to put together valid measures for two dimensions of knowledge—observability and system-embeddedness. While we attempted to measure a number of other dimensions such as teachability, they did not come out well in the statistical analysis. It seems that if we are to progress much further in knowledge management research, some more careful scale development work will have to be done.

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Appendix 1. Measurement of Constructs

R&D Unit Autonomy. We used the 14-item scale developed by Hedlund (1981), which following factor analysis was reduced to a 6-item scale with good reliability (alpha = 0.86). Wording as follows. *Please indicate who makes the decisions regarding (1) the R&D budget, (2) the overall direction of rhe R&D unit's efforts, (3) which new R&D projects to pursue, (4) product design, (5) documentation standards, (6) frequency and format of reports for R&D results. Where 1 = decided independently by subsidiary, 2 = decided by subsidiary after consultation with HQ, 3 = decided by subsidiary but subject to approval by HQ, 4 = decided by HQ after consultation with subsidiary, 5 = decided by HQ.*

Interunit Integration. Based on Lawrence and Lorsch's definition of integration (1967), we measured integration as the sum of three separate questions. *(1) On how many occasions last year did you or other personnel from your R&D unit go to technical meetings organized by your company, (2) On how many occasions last year did you or other personnel from your R&D unit visit other R&D units in your company, (3) On how many occasions last year did your unit receive visitors from other R&D units in your company (1 = never, 2 = once, 3 = 2–4 times, 4 = 5–10 times, 5 = more than 10 times).* Cronbach's alpha = 0.75.

Observability of Knowledge. We used the measure developed by Zander and Kogut (1995). This scale had three items with good reliability (Alpha = 0.86). Wording as follows. *(1) A competitor can easily learn how to manufacture our product by studying our manufacturing employees at work, (2) A competitor can easily learn how to manufacture our product by taking a tour of our plant, (3) A competitor can easily learn how to manufacture our product by examining our machines (1 = totally disagree, 7 = totally agree).*

System Embeddedness of Knowledge. This construct was built on measures developed by Zander and Kogut (1995), as follows. *(1) For our most important product, knowledge about many different technologies needs to be combined, (2) the tasks of R&D units cannot be divided between units since all equipment needed must be kept in one location, (3) the tasks of R&D units cannot be divided between units since the tasks demand daily face-to-face communication between personnel, (4) we can achieve satisfactory product quality only because of our firm's long experience with the manufacturing technology, (5) to achieve high product quality it is very important that our R&D personnel has long experience in the specific R&D unit in which they are working, (6) workers in important parts of the manufacturing process have to be in constant contact with engineers or product quality will go down (1 = totally disagree, 7 = totally agree).* Cronbach's Alpha = 0.69.

Knowledge Transfer. Following discussions with the reference group, we decided that the most appropriate way of tapping into the level of knowledge transfer was to focus on (a) active cases of transfer, rather than transfers that occurred as a by-product of something else, and (b) technological know-how, rather than some of the more codifiable aspects of knowledge such as patents, and (c) transfers to either R&D *or* manufacturing units within the firm. Thus, the exact wording of the questions was as follows. *In the last five years has your unit actively transferred locally developed technological know-how to other manufacturing or R&D units in your company? (no, yes to units in Sweden on ______ number of occasions, yes to units outside Sweden on ______ number of occasions).* The two answers (transfer to Sweden, to other countries) were averaged (Alpha = 0.86).

Research Focus of R&D Unit. Measured as the percentage of total R&D work devoted to "research and product development" rather than "improvement and adaptation" work.

Local Focus of R&D Unit. Measured as the percentage of total R&D work devoted to the local, rather than the international, marketplace.

Cultural Distance. Using the well-established index of Kogut and Singh (1988), this measures the "distance" of the R&D unit from headquarters in Sweden in terms of Hofstede's (1980) four dimensions of national culture.

Age of R&D Unit. Measured as the year the R&D unit was established as a greenfield operation or acquired.

Unit Size. Measured as the number of employees in the R&D unit.

Firm/Industry Dummies. We created firm dummy variables for *Ericsson, Alfa Laval and ABB.* These three were chosen because they had 22, 17, and 23 respondents (respectively) in our sample. No other company had more than 9 respondents.

Endnotes

[1]Neither is it simple to define technology. Our preference in this paper is to use Perrow's definition: "The action that an individual performs upon an object, with or without the aid of a tool or mechanical device, to make some change in the object."

[2]Technology is often viewed as more or less identical to knowledge assets. Here, however, we define knowledge assets more broadly to also include human capital, patents, brands, and organizational routines.

[3]Bartlett and Ghoshal's black-hole subsidiaries, for example (1986), are chronically underperforming subsidiaries that have been given a "strategic" role that is not a good fit with the local market or their

capabilities. As independent companies they would have been selected out, but as part of a larger corporation they are able to survive as long as corporate management believe they are performing a useful role.

[4]The impact of physical context on technology development is considered in a much broader sense in the literature on the sociology of technology (Bijker et al. 1987, MacKenzie 1995). It is also given some attention in other management literatures, such as the transfer of management practises between locations (Brannen et al. 1998, Kogut 1991, Leonard Barton 1995) and the development of knowledge in supplier-customer relationships (Håkansson and Johanson 1992).

[5]Common questions were the measure of the characteristics of knowledge, and the integrating mechanisms questions. For the 22 valid pairs, i.e., those in which we had both subsidiary unit and corporate manager responses, the interrate reliability using Cohen's Kappa (Perreault and Leigh 1989) was 0.68 (knowledge characteristics) and 0.77 (integrating mechanisms).

[6]We made several checks regarding the underlying assumptions of OLS regression. Inspection of the residual plots revealed that the standardized residuals were normally distributed, and that the variances of the error terms were approximately equal (i.e., indicating homoscedasticity). We also checked for multicollinearity. The variance inflation factors were all below 2.0, but the relatively high correlation (0.50) between Local R&D focus and Cultural Distance was still a cause for concern. We reran the models without one and then without the other, and there were no material differences in the results, so both were left in for the reported results.

[7]Note that observability and system embeddedness had to be reversed before multiplying them by integration because the hypothesized relationship is that higher levels of these two variables will be associated with *lower* levels of interunit integration).

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