Explorations of the Impact of "Sticky" Local Information on the Locus of Innovation: A Progress Review

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ABSTRACT

In this article we briefly summarize our work to date on the impact of sticky information on the locus of innovation. First, initial empirical work has shown a link between information stickiness and the locus of innovation-related problem-solving. Second, a pattern of iterative shiftings has been shown in the locus of problem-solving work that appears to be related to problem-solvers' needs for access to sticky information located at two or more sites. Third, we have proposed that such iterative shiftings can be reduced by repartitioning an overall innovation task into subtasks that can each be performed at a single site containing sticky information, and have seen movement towards such a pattern in two industries studied to date. Forth, we propose that the economics of sticky information, combined with advances in computerization, are leading to an increasingly common pattern of innovation task partitioning in which users are "empowered" to customize products and services for themselves at user sites.

1. Introduction

In the early 1990's my students and I began a program to explore the impact of "sticky" local information on the locus of innovation. We were first led to this subject by the response of some innovating users to a question we had asked in a series of interviews: "Why did you decide to develop X innovation yourself rather than asking a manufacturer to do it for you?" In addition to the expected responses regarding economic incentives, there was a very interesting additional element present. A number of interviewees volunteered that they had decided to develop their innovation themselves because they felt it would be very difficult to accurately tell a manufacturer what they wanted.

Interviewees reported that, in part, this anticipated difficulty was due to the fact that their need for the innovation in question did not pre-exist the innovation itself in a stable form: that is, their need and the ultimate solution to it (their innovation) were in fact being co-evolved during the problem-solving work that ultimately resulted in the innovation. An additional source of difficulty was that their need-related information was for various reasons not easy to transfer to the manufacturer: "Even when we know what we want, it is not easy to describe our needs accurately and completely." We found both of these points very interesting, and have begun to explore both. Our explorations of "sticky" information are addressed to the second issue raised by the interviewees, and a progress report on this matter is the topic of this present paper.

2. Information is often sticky

Our explorations of sticky information began with a review of the arguments and findings of the many researchers who have explored information transfer costs. In general, these researchers found that information was indeed often costly to transfer from place to place. Several non-exclusive explanations have been advanced for this phenomenon. Thus, Polanyi pointed out that much information associated with human skill and expertise is "tacit." That is, "the aim of a skilful performance is achieved by the observance of a set of rules which are not known as such to the person following them" (Polanyi 1958, 49, italicized in original). And, "an art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice..." - a relatively costly mode of transfer (ibid., 52,53). Nelson pointed out that technological knowledge is "partly a private good and partly a public one" (1990,1), that is: (1) "a set of specific designs and practices," and (2) "a body of generic knowledge that surrounds these and provides understanding of how things work..."(1990,8). The former is often relatively costly to learn about and to use (1980,1981); often developed in the interaction of R&D and other functions in the firm (Nelson and Winter 1982); and thus private to its creators, "at least when new" (1990,13). Rosenberg emphasizes that while theoretical knowledge derived from science has a role in technical advance and can be diffused at low cost, much technological knowledge is costly, difficult, and slow to diffuse since it deals with "the specific and the particular" (1976,78); takes place in "innumerable small increments..."(ibid.); is tacit and sometimes "even resists formalized statement or codification (ibid.).

In addition, several scholars pointed out that recipients of transferred information must often incur additional costs in order to use it – which, if one regards information as not being really transferred until it is usable, can be viewed as part of information transfer costs as well. Thus, Pavitt observes that "there are very few free technological lunches. Even borrowers of technology must have their own skills, and make their own expenditures on development and production engineering; they cannot treat technology developed elsewhere as a free, or even very cheap, good" (1987,186). Similarly, Evenson and Kislev observe with respect to the economic impact of scientific research on agricultural productivity that "little knowledge is borrowed if no indigenous research takes place" (1973,1314). And Cohen and Levinthal argue that a firm's absorptive capacity with respect to new, external information is largely a function of the firm's prior related knowledge. "At the most elemental level, this prior knowledge includes basic skills or even a shared language but may also include knowledge of the most recent scientific or technological developments in a given field"(1990,128).

3. Sticky information and the locus of innovation

It seemed to us, given the comments of interviewees noted earlier, that it would be useful to explore the impact of information transfer costs on the locus of innovation. To obtain a direct and uncomplicated focus on this issue, we decided to explore the impact of information transfer costs *independent of the reason for those costs.* Accordingly, we defined the "stickiness" of a given unit of information in a given instance as simply the incremental expenditure required to transfer that unit of information to a specified locus in a form usable by a given information seeker – independent of cause. (Thus, whether it was found to cost $100,000 to transfer a given unit of information to the information seeker because of encoding issues, and/or because of absorbtive capacity issues and/or because an information holder demanded $100,000 to grant a license to use that unit of information (which could otherwise be costlessly transferred), the stickiness of that unit of information is the same from the point of view of our definition of the term.)

Our basic hypothesis regarding the impact of sticky information on the locus of innovation is a simple one: When information transfer costs are a significant component of the costs of innovation-related problem-solving work, there will be a tendency to carry out that work at the locus of sticky information, other things being equal. (Analogous arguments are commonly made with respect to materials transportation costs in the case of factory location. E.g., it is reasonable that a firm locate its materials-processing factory at a site that will minimize total input and output transportation costs, other things being equal.)

We reasoned that this general hypothesis could be applied to the locus of innovation-related problem-solving involved in the development of a new product or service – innovation user versus the innovation manufacturer. It seemed applicable to this setting, because in product and service development two information bases located – at least initially – in physically different places are typically important for successful problem-solving. The first is information on need, located initially with the user. The second is information on solution technologies, often located initially at the site of manufacturers specializing in those technologies. In this case, then, the general hypothesis became: all else being equal, if need information required for a specific innovation is "stickier" than required solution information, we should see an increase in the amount of innovation-related problem-solving that is carried out at the site of the user. Conversely, if solution information is stickier than required need information, we should see an increase in the amount of innovation-related problem-solving that is carried out at the site of the manufacturer.

Recently the first empirical test of this idea was carried out by Susumu Ogawa (1998), with findings that were strongly in support of the hypothesis. Ogawa's innovation sample was 24 equipment innovations produced by NEC, a Japanese equipment maker, for Seven-Eleven Japan (SEJ), a major Japanese convenience store chain. These innovations implemented improvements to SEJ store inventory management practices, and were developed and installed in SEJ stores between 1978 and 1992. Ogawa developed proxies based on information novelty for the stickiness of major elements of the need and technology information required to develop the innovations in his sample.[1] He also argued that his findings were relatively independent of user and manufacturer expectations regarding the Appropriability of innovation-related benefits, due to the effect of an agreement between NEC and SEJ that covered the entire series of innovations.[2]

Ogawa determined that increases in need related information stickiness were significantly correlated with increasing amounts of innovation-related problem-solving being carried out by the user. (Kendall correlation coefficients = .5784, $P< .01$). He also

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[1] Ogawa measured the stickiness of <u>need</u> information that would be required by a manufacturer-based problem solver to develop the innovation in question in terms of the number of user inventory management "activities" affected by an innovation that were not already previously known to the manufacturer. (By "previously known," he meant "the same activity was already delivered to SEJ by an equipment produced by NEC.") He measured the stickiness of <u>technology</u> information that must be transferred to the user in order for the user to specify the technical means to implement the innovation in terms of the number of "component technologies" affected by the innovation that were not already previously known to the user. (By "component technologies," he meant "technology (e.g. LCD display) that can be relatively independently developed as one part of the whole product." By previously known," he meant "previously used by SEJ in a store inventory management application.")

[2]. Ogawa reports that NEC and SEJ had an agreement that applied to all innovations in the sample. In that agreement, NEC agreed to sell innovations developed with SEJ <u>only</u> to SEJ for two years – about the length of time that either side might expect to be able to garner monopoly rents from the innovations. This arrangement held independent of the relative level of each firm's contribution to the innovation development work in any particular case.

found that stickier technology-related information was associated with increasing amounts of the technology-related problem-solving being done by the manufacturer (Kendall correlation coefficients = -. 4789, $P < .05$).

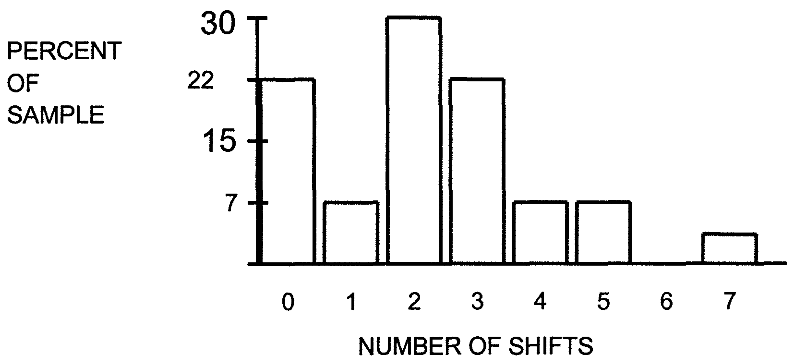
4. Iterative shifts in the locus of problem-solving

A second proposal regarding the impact of information stickiness on the locus of innovation-related problem-solving was that, when the solving of a given problem requires access to sticky information located at two or more sites, problem-solving activity will be observed to move iteratively among those sites. This proposal was based on the finding of others that problem-solving in general (Baron 1988, PP 43-47) and technical problem-solving in particular (Allen 1966, Clark and Fujimoto 1991, Hauschildt 1986, Iansiti 1997, Marples 1961, Smith and Eppinger 1997, Wheelwright and Clark 1992, Thomke 1997)) has trial and error as a prominent feature. If and as each cycle of a trial and error process requires access to sticky information located at more than one site, it seemed reasonable that iterative shiftings of problem-solving activity among sticky information sites would occur as problem-solving proceeded.

To get insight into this pattern, my colleague Marcie Tyre and explored the innovation-related problem solving involved in identifying and diagnosing 27 field failures in process equipment used to automatically assemble complex circuit boards (von Hippel and Tyre 1995). We documented repeated shifts in the locus of technical problem-solving activity occurring during this work, with the number of shifts found ranging from 0 to 7, and averaging about 2.3 times per problem identified and diagnosed (Figure 1). These shifts involved engineers traveling back and forth between development lab and plant (two to three hours by car), carrying out technical problem-solving activities at each site, and carrying intermediate findings back and forth in their minds and/or computer data disks. For example, to begin the diagnosis of a machine that was failing in the field, the designers of that particular machine would often visit the plant where it was being used in order to observe the malfunction in context and run diagnostic tests. Then they would return to the development lab (the site of specialized lab equipment, relevant expertise, and other types of information) to examine the test results and continue their diagnostic work. Often this work would lead to the need for a second trip to the field for more data collection, and so forth. Exploration of the motivations for each such shift to a different site showed that, more than 80% of the time, the motivation had to do with getting access to "situated" information located at that site (Tyre and von Hippel 1997).

FIGURE 1

NUMBER OF SHIFTS BETWEEN PLANT AND LAB DURING PROBLEM SOLVING



The likely ubiquity of iterative shiftings of the locus of problem-solving during product and service development is suggested by the emergence of product development procedures specifically designed to implement such a pattern. For example "rapid prototyping" is a method of software development explicitly designed to shuttle repeatedly between manufacturer and users. A number of individual case studies and experiments have shown that rapid prototyping methods are not only less costly than traditional, noniterative methods but are able to "better satisfy true user requirements and produce information and functionality that is more complete, more accurate, and more meaningful" (Connell and Shafer 1989, 15; Boehm, Gray, and Seewaldt 1984; Gomaa 1983).

5. <u>Sticky Information and "Task Partitioning"</u>

The observation that sticky information considerations would often lead to a pattern of problem-solving that involved iteration among two or more problem-solving sites led us to explore whether there could not be some alternative to this pattern. After all, as is common experience, iteration can be very costly with respect to time and effort.

Thus, no patient likes the shuffling back and forth and time lags involved when a medical condition involves even routine diagnostic tests by and coordinated problem solving among several physicians in different specialties. And, similarly, no designer likes the cost in time and money and frustration involved in repeated redesign of a finished product or service as a result of new information uncovered as a result of test marketing conducted at user sites.

Our search for an alternative to iteration led us to propose that, when the information transfer costs of iteration are high, innovators may find it advantageous to partition innovation-related problem-solving activities that require access to multiple loci of sticky information into subproblems that each draw on only one such locus of sticky information. In the specific context of product and service design, we reasoned that the overall design problem would be partitioned into (1) an application-specific portion that drew upon user-based sticky information for solution and would be solved by users and, (2) into a general solution plus customization tools portion that would be developed by manufacturers.

Our first empirical exploration of this possibility addressed the evolution of the partitioning of product and service customization work between users and manufacturers in two fields: Application-Specific Integrated Circuits (ASICs) and Computer-Telephony Integration (CTI) (von Hippel 1998). In both cases, we did find a task "repartioning" taking place that did in fact convert the overall task of creating custom products into a user sub-problem and a manufacturer sub-problem, each of which could be solved by drawing largely upon sticky local data residing at each of these two sites.

As illustration, we will briefly outline how custom integrated circuit development has been repartitioned between users and manufacturers as a result of a transition from traditional methods of designing custom circuits to the current ASIC design and manufacturing process. In the design of custom integrated circuits, two sticky data bases are central to the problem-solving work: (1) information at the circuit user locus involving a rich and complex understanding of both the overall application in which the custom integrated circuit will play a role and the specific function required of that circuit; (2) information at the circuit manufacturer locus involving a rich and complex understanding of the constraints and possibilities of the silicon fabrication process that the manufacturer uses to produce integrated circuits.

Traditionally, custom integrated circuits were developed in an iterative process between a circuit user possessing sticky need information and an integrated circuit manufacturer possessing sticky information about designing and producing silicon integrated circuits. The process would begin with a user specifying the functions that the custom chip was to perform to a circuit design specialist employed by the integrated circuit manufacturer. The chip would then be designed at the manufacturer locus, and an (expensive) prototype would be produced and sent to the user. Testing by the user would typically reveal faults in the chip and/or the initial specification, responsive changes would be made, a new prototype built, and so forth.

More recently, the Application Specific Integrated Circuit (ASIC) method of making custom integrated circuits has come into wide practice. In the ASIC method, the overall problem of designing custom circuits is partitioned into subproblems which each draw on only one locus of sticky information, thereby eliminating the need to iterate between two such sites in the design process. The manufacturer of ASICs draws on its own sticky information to develop and improve the fabrication processes in its manufacturing plant, a "silicon foundry." The manufacturer also draws on its own sticky information to design "standard" silicon wafers that contain an array of unconnected circuit elements such as logic gates. These standard circuit elements arrays are designed by the manufacturer to be interconnectable into working integrated circuits by the later addition of custom interconnection layers designed in accordance with the needs of specific users.

The interconnection design task is then partitioned from the device design task and is taken on by users. To facilitate this user design task, the manufacturer provides custom circuit users with a user-friendly Computer-Aided Design (CAD) software package that enables them to design a custom interconnection layer design to meet their specific application needs and yet stay within the production capabilities of the manufacturer's silicon foundry. This CAD software also allows the user to simulate the function of the custom circuit under design, and to conduct trial-and-error experiments. Taken together, these capabilities allow the user to both design a circuit, and to refine need specifications and the desired circuit function through an iterative process that draws only on sticky information located at the user site. In sum, by partitioning the overall circuit design task into user-based and manufacturer based subtasks, the ASIC method of designing custom integrated circuits reduces the need for the iterative shifting of the locus of innovation-related problem solving between user and manufacturer.

6. Summary and Discussion

Work to date has shown a link between information stickiness and the locus of innovation-related problem-solving. A pattern of iterative shiftings of problem-solving work has also been documented, with a possible explanation being problem-solvers' iterative needs for access to sticky information located at two or more sites. Finally, an argument has been made that this need for iteration may be reduced by "partitioning" innovation-related tasks drawing upon multiple sites of sticky information into two or more subproblems, each drawing primarily upon a single site of sticky information. A case study has documented such a pattern in two fields.

We now conclude this progress report by proposing that many fields are evolving or will evolve towards a pattern in which application-specific design of product and services will be partitioned from the more general tasks of product and service development, and will increasingly be transferred to users when: (1) the supplier faces heterogeneous demand for a given type of product or service (that is, many of the users served place a high value on custom solutions); (2) agency costs experienced by users who outsource design activities are high; (3) the stickiness of application-specific user information is high; and (4) the stickiness of information held by suppliers that is relevant to application-specific problem-solving is low (von Hippel 1998).

We elaborate on this point by first noting that that the stickiness of a given body of information is not immutable. Thus, when the costs of iteration are considered to be high, efforts will sometimes be directed toward investing in "unsticking" or reducing the stickiness of some of the information. For example, firms may reduce the stickiness of a critical form of technical expertise by investing in converting some of that expertise from tacit knowledge to the more explicit and easily transferable form of a software "expert system"(Davis 1986). Or they may invest in reducing the stickiness of information of interest to users by converting it into a remotely accessible and user-friendly computer data base. This is what the travel industry did, for example, when it invested substantial sums to put its various data bases for airline schedules, hotel reservations, and car rentals "on-line" in a user-accessible form.

An investment in unsticking a unit of information is a one-time investment that reduces the marginal cost of all succeeding transfers of that information. Therefore, the incentive to invest in reducing the stickiness of a given unit of information will vary according to the number of times that one expects to transfer it. As illustration, suppose that to solve a particular problem, two units of equally sticky local information are required, one from a user and one from a supplier. In that case, there will be an equal incentive operating to unstick either of these units of information in order to reduce the cost of transfer, other things (such as the cost of unsticking) being equal. But now suppose that there is reason to expect that one of the units of information, say the supplier's, will be a candidate for transfer n times in the future, while the user's unit of information will be of interest to problem solvers only once. For example, suppose that a supplier expects to have the same technical information called on repeatedly to solve n user product application problems, and that each such problem involves unique user information. In that case, the total incentive to unstick the supplier's information across the entire series of user problems is n times higher than the incentive for an individual user to unstick its problem-related information.

In the case of the problem-solving work of product and service development, the situation just described is the one often encountered in the real world. Manufacturers do tend to specialize in a given solution type, which they attempt to apply to the diverse application problems of many users. Also, the local information required from a supplier to solve each novel application problem tends to be the same, while the local information required from the user tends to be novel or have novel components. Under such conditions, and for the reasons just described, we expect that sticky information transfer cost considerations will create an incentive to shift the locus of problem-solving activity to the locus of the less frequently called-upon information - in the case of our example, to the user. (As illustration, recall the shift from the traditional iterative method of designing custom integrated circuits to the ASIC task partitioning method that we described earlier. During the problem-solving work of circuit design, each circuit designer requires access to the same information about the constraints of the circuit manufacturing process, but requires different information about the specific application being designed for. As a consequence, the ASIC manufacturer found it economic to unstick the repeatedly called-upon production process information by investing in encoding it in a user-friendly CAD package. And, as a further consequence, the problem-solving activity of custom circuit design was shifted to the locus of sticky information regarding each unique application - the user.)

We propose that user-based design is becoming and will become an increasingly attractive option in many fields due to advances in computerization. More specifically, improvements in computer hardware and software are allowing "unstuck" supplier information to be shifted to users in increasingly user-friendly and more capable ways. Consider, for example, that it has always been possible for a integrated circuit manufacturer to unstick key process information and transfer it to user-based designers. In earlier days, however, that information would have been unstuck by encoding it in a process specification sheet or booklet, and it would have been up to the user-designer to know when a particular bit of information was relevant to his or her design, find the booklet and look it up. Today, process information can be embedded in a computerized design tool, which can be programmed to offer the user items of process information only if and as the design being worked upon makes them relevant. For example, a simulation tool can be programmed to tell a designer that "your design is getting too big to process on a single chip" only if and as the user is approaching that particular limit to the available solution space. More generally, the ability to encode unstuck problem-solving expertise in user-relevant language may not have changed over time, but the ability to offer this translated information conveniently and appropriately connected to the design work itself certainly has been greatly improved as a result of technological advance.

We hope that this brief progress report will stimulate the reader to think about joining in on the research regarding information stickiness and the locus of innovation. Our own work during these past few years has only been able to sketch out some interesting linkages between sticky information and the locus of innovation via theory-building and case studies. We think that a great deal more interesting work remains to be done before this area can be considered to be well explored. Among the interesting issues still to be considered: explorations of patterns of information stickiness may enable us to understand more about patterns of specialization among firms. Since an organizational boundary can add to the cost of information transfer, it seems likely that firms seeking to economize with respect to the transfer of sticky information will seek to align their organizational boundaries - and their specializations - with the partitionings dictated by the types of innovation-related problem-solving tasks that are important to them. For similar reasons, consideration of the impact of sticky information may be useful in studying the various collaborative innovation patterns that are being practiced by firms today (e.g., Gemunden 1980). We also propose that studies of sticky information can increase our understanding of how firms protect, sell, trade, diffuse, and appropriate benefit from information. Thus, stickiness can help the possessors of valuable information to prevent unintentional diffusion to competitors, but that same property may make it more costly to diffuse the information intentionally.

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