Innovation and Location:
A Case Study of Sony's Vaio Laptop

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Abstract

This article investigates the question of why innovation has been geographically concentrated. Although many past studies of regional institutions, social networks, and tacit knowledge have provided insight into this question, they have done little to probe the engineering and technical aspects of the phenomenon of the place-rootedness of innovation. This study approaches this question through an empirical analysis of innovation at the micro-scale, a case study in the product development of Sony's Vaio 505 laptop. It uncovers three specific features in the process of innovation: complexity, the interdisciplinary development of technology, and prototyping and testing. Each of these engineering and technical aspects requires the co-location of the engineers and managers of the innovation project.

Keywords: innovation, location, Japanese firms

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Introduction

It has been generally understood that corporate research and development (R&D) activities have been globalized. Transnational corporations often operate R&D centers at the cross-continental scale: in Europe, North America, and Asia. Many of them claim that their global R&D network synergistically creates new technologies and products. For example, Sony (2004a) explicitly calls for "a global synergy in R&D" with its ten operating R&D centers in the world, and Canon's "R&D centers around the world try to develop creative products and solutions for Canon as a whole" (Canon 2006).

A close analysis of Sony, conventionally viewed as a highly globalized firm, reveals that over 95 percent of its R&D not only occurred in Japan, but more specifically in the southern Tokyo region. Moreover, virtually all of its most famous products - the Walkman, Passport video camera, Vaio laptop, AIBO robot, PlayStation game machine, and flat-panel screen technology - were created by development teams located in Japan (Aoki, interview, September 21, 2004; Arimura 1999).

This article investigates the question of why such geographic concentration of R&D is critical. Past studies to answer this question could be grouped into three schools of thought: the institutional, social network, and tacit knowledge schools. We will review how each school answered the reasons for concentration and assesses their limitations. In essence, little has been investigated on the engineering aspect of making innovation, which has crucial connection to a specific location. It is hard to analyze such a technical aspect of innovating if the main unit of analysis is a region. Inevitably, the concept of innovation becomes generic at such a broadly defined scale. Simply put, regions, as an aggregate unit, do not produce innovation, while we may observe a number of industrial or social innovations within a region. Thus, if someone speaks of "an innovative region," the scale and concept of innovation loses an explanatory power. In contrast, this article will conduct a micro-level case study and assess a particular product development, specifically how Sony developed its first stylish laptop, the Vaio 505 in the late 1990s. This in-depth analysis will reveal three features of creating innovation that are inherently tied to geography, thus providing further understanding of the relationship between innovation and regions: the complexity, the interdisciplinary development of technology, and prototyping and testing.

Studies in Industrial Clusters and Japanese Firms

Industrial Clusters

By analyzing the location of patent filing or initial public offerings of high-tech firms, a number of empirical studies support that innovation occurs in geographical clusters (for example, Jaffe et al. 1993; Feldman and Florida 1994; Audretsch and Feldman 1996; Patton and Kenney 2003; Sonn and Storper 2007). This section discusses the conclusions those past studies drew for the reasons for such clusters and introduces three different schools of thought: the institutional, social networks, and tacit knowledge schools. In sum, these schools all argued that innovation was more likely to occur if

Source: Based on Sony (2002) and Sony (2004a), author's calculation.

Figure 1. Sony's Worldwide Research and Development Centers.

people, firms, and other regional and institutional actors were clustered in close proximity to each other.

First, the institutional perspective emphasizes the benefits of a localized learning effect among different economic players in a regional economy (Storper 1997; Morgan 1997; Maskell 2001; Pinch et al. 2003; Lowe, 2009). These studies supported Marshallian positive externalities shared by a pool of labor and the mobility of skilled workers, which would result in spin-offs (Camagni 1991; Scott 2000; Capello & Faggian 2005). More importantly, competition and collaboration between co-located firms spurred the dissemination of knowledge and the interactive learning process (Porter 1998; Antonelli 2006).

The second school of thought concerning innovation and clusters is social network theory, primarily descended from the influential embeddedness theory of Granovetter (1985). This theory analyzes how people exchange information and argues that communication is socially embedded. In this context, the sources and reliability of communication are as important as the rich information that typically comes through trusted relationships cultivated by participants (Hackman & Morris 1978). At the same time, judgment criteria were often highly culture and context-specific (Lakoff & Johnson 1980) and shared by people in the same social group (Coleman 1990).

This network concept has been applied in an economic context. Empirical studies have found that local-based business networks produced higher entrepreneurship and innovation levels in northern Italy (Brusco 1982; Piore & Sabel 1984), the Silicon Valley (Saxenian 1994), and the art and culture sector in New York (Currid 2007). This school of thought emphasizes the role of face-to-face interaction as the richest form of communication, necessarily requiring co-location among participants (Storper & Venables 2004).

The third school of thought is the tacit knowledge theory, based on the work of Polanyi (1966) and Nonaka and Takeuchi (1995). In an information age of relatively easy access to explicit and codified knowledge, innovation depends on tacit knowledge derived from direct interpersonal contact and the dynamic interaction between codified and tacit knowledge (Malmberg & Maskell 2002). While codified knowledge can be transmitted in the form of books, academic papers, and websites, tacit knowledge does not travel easily because it is best shared by people with similar norms, codes of communication, and routines (Howells 2002; Gertler 2003; Zook 2004). Thus, knowledge and innovation clusters in specific regions with a shared business culture and especially within the same organization.

However, the focus of these streams of literature was on how much innovation was observed in a given region, but not on how each innovation was made. The three schools measure innovation by proxies, such as the number of patents, public offerings of ventures, as mentioned earlier, or, more broadly, the growth of a regional high-tech industry as in Silicon Valley (Saxenian 1994). Here, the literature rarely specified what was innovated and how this occurred. In other words, the past literature has assumed that innovation in the form of goods and services would result if firms competed and collaborated or if people met and shared tacit knowledge. This project starts from a hypothesis that the mechanism to create innovation is substantially more complex, and the complex process has deep geographic roots. This analysis on the process of innovation is critical because innovation in contemporary society is in good measure an engineering and technical matter. If we miss the analysis on the technical process, we may be missing the fundamental nature in the making of innovation and its linkage to the location.

To investigate the specificity of innovation and the process of making it, more in-depth examinations can emerge by focusing on activities of economic actors. This article focuses on innovations at the concrete micro-level and analyzes the product development activities of a firm. Only after differentiating which engineer was involved in what kind of innovation can you start to analyze the process of generating a specific innovation and understand its connection to geography.

Innovation at Japanese Firms

As we examine the innovation activities conducted by Sony, we have to keep in mind both the advantages and disadvantages of studying a Japanese firm. It is advantageous to study Japanese firms because there are many successful ones in innovation-intensive industrial sectors with an engineering orientation, such as machinery, electronics, and computers. Sony is a well-known player in the electronics and computer sectors, sectors that provide a good sample in exploring the specificity and the process of making innovation.

Second, Japanese firms have a high international presence, and conduct sales, distribution, and manufacturing at the global level. Thus, the geographic concentration of innovation-making activities contrasts sharply with the global manufacturing and sales operation; this dichotomy indicates strategic reasons for such concentration.

At the same time, what this project uncovers could apply only to Japanese firms due to their specific cultural and organizational characteristics. Indeed, past studies in business, economics, and political economy have identified several unique features of Japanese firms. Gerlach (1992) and Lincoln and Gerlach (2004) revealed the stable networks of business relationships, including cross-shareholding and supply networks within a keiretsu group. Aoki (1988) and Aoki and Dore (1994) discussed the aspect of the unique labor system in which unions, often organized at the enterprise level instead of the industry level, and management have maintained a relatively harmonious relationship based on the life-time employment and seniority-based wage system.

In addition to these general characteristics of Japanese firms, two groups of studies discussed the unique patterns of Japanese firms related to innovation. First, Fransman (1999 p.159-160) specifically analyzed how the labor-management relationship affected the innovation system. Under the life-time employment system, firms assumed that their employees would not quit, and thus it gave firms an incentive to invest in and train employees. It further promoted job rotation within the company and information sharing between the marketing, production, and R&D divisions. This insight echoed Fruin's (1992, 1997) findings that there existed a close interaction between the production and R&D units. Second, Nonaka and Takeuchi (1995), and Shibata and Takeuchi (2006) argued that the strength of Japanese firms came from the organizational practices of sharing tacit knowledge and promoting the dynamic interaction between the tacit and explicit knowledge.

These studies, however, provided few indications of how the uniqueness of the innovation system among Japanese firms shapes the geography of innovation. It is unclear if the close supplier relationship enforces geographical proximity or whether such close relationship allows the distant yet effective coordination between networked firms. Similarly, the close labor-management relations may suggest the operation of manufacturing and R&D divisions in geographic proximity or in distance. In other words, the geographic analysis of the innovation system in Japanese firms is a vacuum in the past studies. So far, the only implication for geography comes with the concept of the sharing of tacit knowledge, which suggests the face-to-face interaction between innovators and the proximate environment.

One notable exception in the study of geography of innovation by Japanese firms came from McCann and Arita (2002), who reported that the extreme secrecy of the semiconductor industry made the location of R&D units and trial plants unrelated to the regional cluster of firms often discussed by the economic geography literature. In other words, firms collaborated based on their strategic alliance, in which supplier firms were located both within a region and outside the region.

In sum, the literature above suggested that the unique behavior of Japanese firms would not necessarily result in the geographic concentration of innovation activities. Therefore, findings from this study may not be constrained only to Japanese firms, while investigating how and how much those findings will apply to non-Japanese firms requires another set of research. Here, it is important to limit the scope of this project: This is exploratory research to uncover the linkage between the process of innovation making and geography. An in-depth case study is an effective methodology to disentangle such relationships. At the same time, this project will not aim to generalize findings to all types of innovations by all types of firms. Nor does the project intend to argue that the findings would persist forever. This project presents a snapshot of a particular industry and a case study of a Japanese firm. Nonetheless, this article can contribute as a first step to analyze how the engineering and technical aspects of innovation making could be tied to geography.

Investigating the Specificity of Innovation

Research Design

This article will examine innovation at the "nuts and bolts" level and will use a case study of specific product development. An analysis at the product development level is advantageous because it is a highly visible form of innovation, in contrast to less visible innovation in the manufacturing process or organizational form. The investigated product was the Vaio 505 laptop created by Sony. This product provides an appropriate focus for a case study for two reasons. First, it was an innovation-intensive product. Its new features and miniaturization required a large set of technological challenges, and the development team had to overcome them by generating various innovations. In other words, the Vaio 505 was not a laptop marginally improving on its predecessors simply with a faster processor or larger memory. Second, it was a successful product with a significant impact on the market. The Vaio 505 innovation was highly regarded because it made Sony one of the major players in the PC industry in both Japan and the U.S. Before this Vaio model, Sony had captured only one percent of the market share in laptops (McWilliams 1997). After its introduction, this Vaio laptop became the top-selling model, and its following models pushed Sony's market share up to second in the market, 25.2 percent, falling only behind Compaq (CNET News 2001).

This study uses a corporate historical case study approach pioneered by Hounshell and Smith (1988). There were two data sources for the analysis: (1) an archival and document search, and (2) company interviews. The author started with building an archive from journalistic reports, business magazines, and corporate websites discussing the Vaio laptop making. Since Sony is an internationally regarded firm, there were plenty of materials covering specific product development processes and organizational dynamics in detail. Then, the author conducted semi-structured interviews; the project leader was the best source of information (Ito, interview, September 24, 2004), while other project members were also informative (Endo, May 7, 2004; Sakaguchi, July 21, 2004; Aoki, September 21, 2004; Tambata, September 24, 2004; Iguchi and Miyano, December 4, 2004). Both sources were critical and complemented to understanding the in-depth process of making the product.

Sony Before the Vaio 505

The Vaio was not the first PC created by Sony. The company's history of PC production goes back a few decades. Sony first produced a transistor-based calculator, SOBAX, in 1967. It eventually pulled out of the calculator business due to fierce price competition from Sharp and Casio, two other Japanese producers (Kawaguchi 2003 p.66). In 1982, Sony collaborated with Panasonic and introduced the SMC-777, based on the open MSX standard developed by Microsoft, a project led by Nobuyuki Idei. A former CEO of Sony, he aggressively started the Vaio business after 1996. Sony had a string of failures include the NEWS, a workstation, in 1987, the AX in 1988, and the IBM-compatible QuarterL in 1993 (Sony-EMCS 2005). Despite these failures, Sony stayed in the PC industry by OEM to Dell and Apple in the 1990s. Yet it was a long-standing wish of Sony to produce its own brand of PCs.

Progress in information technology in the mid-1990s brought another business opportunity for Sony. Household consumers in Japan started to use PCs not only for traditional word processing, but also for graphics, music, and games. This opened up the possibility of audiovisual use for PCs, and Idei considered this as the company's next primary market. VAIO is an acronym for Video Audio Integrated Operation and explains Sony's ambition to integrate PCs, telecommunication, music, and movies. Sony started to produce its first Vaio series in desktop, MiniTower, and notebook forms in July 1997. While it was introduced simultaneously in the U.S. and Japan, Michael Dell dismissed it as "the invisible invasion" (McWilliams 1997) despite the fact that Sony spent $20 million on advertising. In sum, the earlier history of PCs at Sony was repeated failures despite its high ambition. The challenge was enormous for Sony, and it had to seek different business models to emerge in the PC market.

The project leader for the Vaio 505, Susumu Ito, joined Sony in 1982, and became involved in the development of the company's earlier PCs. As Sony exited the market each time yet maintained its ambition to re-enter the market, Sony assigned him to continue to work on the development of peripheral devices for PCs. In 1994, Ito was stationed in Mountain View, California, working on the development of mobile terminal devices in collaboration with Apple, Motorola, and AT&T. At the start of 1996, a Sony executive called him back to Japan to develop a new PC with the Sony name (Ito, interview, September 24, 2004).

The Development of the Vaio Concept

The Vaio project officially started in October 1996 with six members: Ito, the chief engineer; three electrical engineers; one software engineer; and one designer. [1] Five engineers were

[1] In general, engineers deal with technical matters, while a designer is in charge of the overall, exterior appearance. However, this

affiliated to the Design Division I of Sony IT Company (Goda 1999) at Sony's Shonan Technical Center located at Fujisawa, 45 km (28 mi) southwest of its headquarters in Central Tokyo. They systematically reviewed the market feasibility of a potential product in comparison with those of its competitors, especially Toshiba and IBM, by discussing the types, prices, and functions of the products already in the market. They tried to find some originality to position the Sony product, which was not easy to achieve. The conventional competition strategy in the PC market at that time was the bigger, the better. The main issue was the size of the memory (Dynamic Random Access Memory, DRAM) or the processing unit (Central Processing Unit, CPU). Sony did not produce its own CPU and had to rely on Intel. Ito and others had learned that the fastest PC with the biggest DRAM would be obsolete in just six months (Ito, interview, September 24, 2004). Additionally, with fierce competition from Korean and Taiwanese DRAM producers, competition over the speed of DRAM would be unprofitable. The discussion went over a month in 1996, and the most important idea to come out of the discussion was the type of concept for the Vaio they should not pursue: A new PC should not compete on the basis of the bigger the better (Ito, interview, September 24, 2004).

Instead, they searched for other qualities in which they could compete. Toshiba and IBM produced laptops, but these were still relatively expensive, normally $3,000 each or higher, and marketed mostly for office use. And they were not true laptops as they have come to be known but bulky, unattractive, and semi-portable. Ito calculated that there would be a market for non-office use. The team developed the design principles of portability and aesthetics that a model was smaller, thinner, lighter, and a different color than competing models (Tambata, interview, September 24, 2004).

Instead of the conventional A4 size (236 x 297 mm), they decided to scale down to B5 size (208 x 259 mm), approximately 15 percent smaller. They figured that scaling down to notebook size would substantially improve the portability of the PC (Ito, interview, September 24, 2004). Ito proposed a thickness limit of 23 mm, in contrast to the previously available 37.6 mm; and a weight limit of 1.35 kg to enhance portability, instead of 2.4 kg (Sony 1997). In contrast to the normal dark-colored, plastic exterior, they decided on a shiny, magnesium body surrounding all parts of the laptop (see Figure 2).

This concept of a slim and light laptop came not only from the five engineers of the project, but also from a designer, Teiyu Goto, who contributed substantially in this process of concept development. Goto, who had been a chief designer for Sony's PlayStation, was positioned at the Creative Center, a design unit of Sony located at the headquarters in Shinagawa in central Tokyo. While Ito and Goto had communicated about the project since late 1996, Goto had to visit the Technical Center at least once a week to participate in the discussion (Ito, interview, September 24, 2004). Although the concept of a new product could be described in one phrase, "portable and good-looking," many other ideas were incorporated. Thus, it

division of labor is not rigid, as we will uncover in this article.

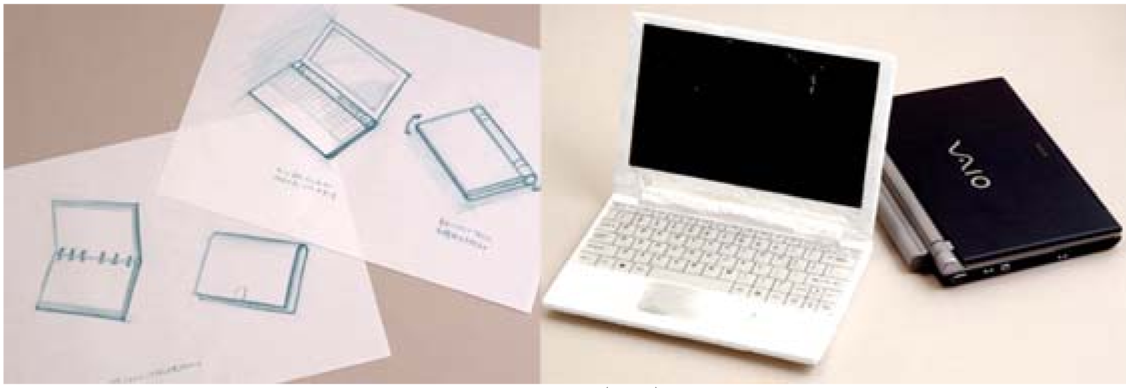
Source: Sony (1997).

Figure 2. Sony's previous laptop,the PCG700 Series (left), and the updated model, the Vaio 505 (right).

was important for Goto to follow what other concepts were debated and rejected. For all the project members, knowing the final meeting decision was not sufficient, and understanding the past debates was critical. Then, Goto could share the concept more deeply by going through what exactly other members meant by "portable" and "good-looking." As a result, they had to conduct all these design discussions at the Technical Center on a face-to-face basis. From the early stage of the project, Goto suggested that clock frequency of CPU would not be important, and the slimness could be the best attraction for consumers (Goda 1999).

As the team confirmed the concept, they started to convert it into an actual design. The period from January to February 1997 was the peak of such brainstorming meetings. They repeatedly drew designs, created prototypes made of paper or polystyrene, discussed the results, scratched it all, and started over. They designated a special meeting room for this project, where they placed updated designs and prototypes (see Figure 3). There were always some members of the project team in this room discussing sophistication and stylishness of the design, use, and functions. This discussion had to be face-to-face and focused on a prototype. Otherwise, ideas and counter-opinions could not be clearly discussed or effectively compared. It was almost impossible to rely solely on oral, non-visual communication. Communication via telephone was undesirable because it could create confusion (Tambata, interview, September 24, 2004; Endo, interview, May 7, 2004).

Information had to be shared by all members in real time. A model design from a previous day was obsolete, and time for a catch-up meeting would be a waste. Additionally, people's ideas would not come out smoothly if any interruption occurred. For example, if one member had missed a meeting the previous day and started to ask why and how the rest of them came up with a different idea, that would require a review of the past information and delay producing ideas for the next step (Tambata, interview, September 24, 2004). Therefore, the



Source: Sony (2003).

Figure 3. Drawings of laptop design ideas (left) and the polystyrene prototype (right).

brainstorming exercises required all involved members to be present all the time. During this peak brainstorming period for two months, Goto came to the Technical Center almost every day (Ito, interview, September 24, 2004).

Component Development

As they consolidated the design, the project members started a search for available components. In February 1997, the project team added four more members: two electrical engineers, one mechanical engineer, and a new director. While the chief engineer, Susumu Ito, led the Vaio project previously, the new director with experience in managing Sony's camcorder projects now supervised the project, and Ito could concentrate on the engineering aspect of the Vaio.

As the name *Vaio* states, it integrated audiovisual (AV) functions into PCs. This integration would include the use of music and audio files in a digitized format (software) as well as the direct ink to a camcorder (hardware). Recruiting AV-oriented engineers was essential. Moreover, since Sony heavily emphasized the user-friendliness in the development process of the camcorder, the addition of this experienced staff was critical. This was in contrast to Ito and other original members, who were dedicated electrical engineers (Ito, interview, September 24, 2004). They were aware of that an engineer's interpretation of style and functionality could vastly differ from consumer expectations. This was an effort by Sony to incorporate as much market-forward feedback as possible even in the designing and production phases. This incorporation of different expertise required the formation of a project team with people of different backgrounds and continuous interaction among them.

Sony's policy was to procure components from its affiliated firms, but the project team did not hesitate to procure components from the market (Ito, interview, September 24, 2004). In relationships with suppliers, they were willing to collaborate and even to invest. For a modem connection, the team looked for a thinner connecting device. The conventional size for a modem connector was more than 25 mm square. However, as the thickness of the Vaio was set at 23 mm, they had to shrink the telecommunication device. The solution proposed by Sony was to eliminate plastics in the connection for the top and bottom of the rim, and the plastic on the left and right sides would still support the connection. This component had been previously procured from a specialized parts supplier, and now the supplier had to make changes in their production line. Accordingly, Sony invested approximately $2 million in the supplier, located in the southern Tokyo metropolitan area.

The collaboration with suppliers extended to a complicated level, involving a potential competitor in the industry. The Vaio 505 monitor was a liquid crystal display (LCD) supplied by market-leading Toshiba, Sony's target competitor in laptops. LCDs were becoming popular in the late 1990s and widely used for laptops. At that time, the market demand was for a larger screen size, since a larger one was easier to see. In contrast, the Vaio 505 required a smaller size, 10.41 inches, in lieu of the conventional 12-inch or 14-inch size. In addition to size, Sony considered it necessary to have a monitor with higher resolution. Vaio was intended to integrate PCs and multimedia, and its expected uses included watching movies, graphic design, and games. The resolution of conventionally available LCDs was not sufficient, and Sony requested that Toshiba develop a new model. Toshiba responded, supplying a smaller, yet higher resolution monitor to its competitor. Toshiba's lab was located in Kawasaki, only half an hour train ride from Fujisawa, an easy commuting distance for attending meetings.

These dynamic processes of component procurement show that relationships with suppliers were complex. It was not as simple or static as Sony telling suppliers what to make and suppliers providing the specified components. Instead, the relationships were dynamic, as Sony and its suppliers continued to discuss, produce, modify, and re-evaluate components. Under such circumstances, it was more convenient to use suppliers that were close to Sony's Technical Center (Sakaguchi, interview, July 21, 2004).

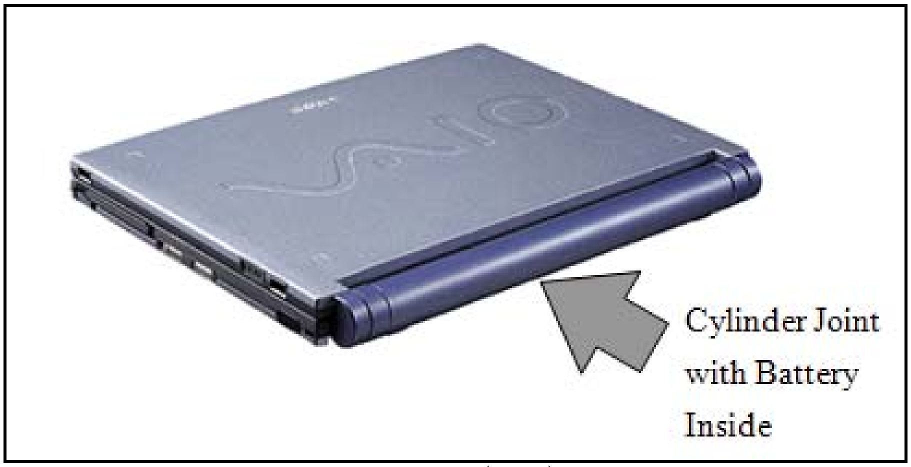
One component that the Vaio team adhered to internal procurement was the exterior body, made of magnesium. It was Sony's first attempt to produce such material in such a thin shape. They believed that the style provided by this skin would be a critical part of the product, and did not want to outsource its production. However, after making a prototype, the design team found that the cost of producing the exterior was considerably higher than expected. Then, they had to consult immediately for cost feasibility. Ito rushed to the headquarters in Shinagawa to discuss the subject with the executive board. Eventually, Ito and the executives agreed that economies of scale would likely solve this cost issue. That is, if the Vaio 505 were to sell as well as expected, the cost per laptop would decrease sufficiently (Aoki, interview, September 21, 2004). This kind of unexpected turnabout in the development project meant that proximity was essential not only between engineers but also between the engineers and the executives at the headquarters.

The design and allocation of components was not a simple spatial matter, but required mechanical and other functional coordination. In one instance, the arrangement of components required the technique of miniature engineering, as well as creativity. Most laptops were equipped with a lithium battery, which was a conventional cylindrical shape and 20 mm wide. With the new Vaio's thickness limit of 23 mm, the location of this battery became a major issue. A laptop must have a keyboard thin enough to be about 5 mm, yet that would leave less than 18 mm left for the battery space. The non-keyboard space must be allocated for other key components of a PC, such as a motherboard with CPU, video slots, and the hard disk drive. The Vaio team considered requesting development of a new thin battery from the Sony's battery division, which was highly competitive in the market. However, they realized this development would be substantially costly in terms of time and budget.

Interestingly, the solution came not from engineers but from the designer. Goto proposed that, contrary to the conventional wisdom, the battery did not need to be located under the main body. Instead, it could be placed at the junction of the main body and the monitor. The conjoining part could be a cylinder shape and could be as thick as both the main body and monitor combined. The project leader immediately accepted the idea, and the Vaio 505 received a distinct cylinder joint at its spine (Figure 4).

Another challenge involving the size and product dimensions was the balance between the miniaturization and the management of technologies related to thermodynamics and software engineering. A combination of several types of engineering technologies achieved the desired small scale of the Vaio. The volume of space taken up by the Vaio 505 had to be reduced to 40-60 percent of the previous model, which meant the heating density of many components soared inside the laptop. In a PC, the heat mainly comes from the CPU. A 133 MHz processor could increase the temperature by 49 ^{o}C. Similarly, a large scale integrator (LSI) would increase the temperature by over 50^{o}C and the hard disk drive by 12^{o}C (Koyanagawa et al. 2000 p.10). Moreover, the engineering team faced an even bigger challenge as they decided to remove a cooling fan to make the body lighter and thinner and eliminate fan noise for aesthetic reasons. To solve these heat problems, they first had to create effective aerodynamics. In what Sony called the "progressive cooling system," they carefully designed ventilation holes so that air would be efficiently brought into and out of the laptop without a fan. They used a computer simulation model to calculate the most optimal structure of the body. Second, they set up heat pipes, which were low in conductivity and could transport heated air efficiently outside the machine. While the computer simulation was useful, they ultimately had to create a prototype to see how much heat reduction each arrangement brought (Iguchi, interview, December 4, 2004). Two mechanical designers described, or complained about this lengthy process of designing, prototyping, testing, and redesigning as follows:

> "With a variety of choices in materials for the body, methods to strengthen body structure, and location of components, it was a process of creating a prototype, abandoning it, and recreating it a few dozen times.



Source: Sony (2004a).

Figure 4. Backside of the Vaio 505.

Some days, I was feeling that we were finally getting closer to the optimal body structure and device location. However, people [other project members] kept providing me new information, such as that there was a better material available, or a request to improve cooling efficiency, and so on. I had to abandon my designing again, again, and again. (*Laugh*.) I tried to be optimistic and told myself repeatedly that we could achieve a better and lighter laptop" (Asawa, cited in Sony 2004).

"Asawa-san [the mechanical design leader] and I coordinated all the time. When the design of the body changed, we re-designed the [mother]board. After the board adjustment, we remade the body. It was a very close and lengthy coordination" (Ishikawa, cited in Sony 2004b).

Miniaturization, a specific type of innovation, involved both electrical and mechanical engineering as well as material science and simulation engineering. It was a trial and error, cut and try process. A change in one component caused snowballing changes in other components. Focusing upon these two mechanic design engineers can allow us to observe the complex coordination in real time.

Information technology was critical for the design process, but did not always provide solutions. Human creativity superseded the efficiency of machines, and higher density came from rule-breaking. The Vaio team used computer-aided design (CAD), and there were rules that every registered component needed a certain space between other components, determined by component suppliers. The suppliers determined this needed space based on the standard use of a component. In reality, not the entire space was necessary as suppliers had suggested, and the Vaio engineers redesigned with an intentional overlap in the space. This overlap could reduce unused space and achieve higher density. However, it required close examination and hands-on placement of every component (Miyano, interview, December 4, 2004). A mechanical engineer checked that no overlap would cause any significant problem. It was an extremely tedious and lengthy process to go over every one of the 1,100 components of the Vaio, but ultimately effective.

Coordination took place not only within the project group, but also between different divisions. From April 1997, they started a project progress meeting every month. This meeting invited key persons from six divisions: design, material, product quality, applied technology, software application, and production. They met in Shinagawa, the corporate headquarters as well as the location of four divisions: material, product quality, applied technology, and software application. The production division was located in Nagano, a three-hour distance from the headquarters, but the personnel commuted to Shinagawa for every meeting. The executives at Shiangawa did not get involved in this meeting directly. However, the project leader made a separate progress report to the executives by sending a meeting memo. "It was important to continually update the progress to both the executive board and related divisions. We [the design team] of course communicated with a specific division on an ad-hoc, as needed basis, but the monthly meeting facilitated our coordination process" (Ito, interview, September 24, 2004). Meetings on an ad-hoc basis when problems arose were not sufficient, and continuous communication was important to set all involved parties understand where the project had stood, what kind of problems they faced, and how they tried to solve previously but unsuccessfully. Understanding such context in the project was critical, and the progress report on a regular basis was needed.

Toward Mass Production

Preparation for the whole production coordination, including that with suppliers, would normally take four months for PCs (Komamura, cited in Sony-EMCS 2004b). To launch sales in November, Sony started to bridge design and mass production in July. Sony outsourced its Vaio production entirely to Sony's Engineering, Manufacturing, and Customer Service (EMCS), its wholly-owned subsidiary located in Nagano, three hours northwest of the headquarters (See the left map on Figure 5). It was Sony's strategy to separate corporate functions into two organizations: Sony IT Company concentrated on product development, marketing and sales, while Sony EMCS focused on mass production and customer services (Sony-EMCS 2005).

Sony bridged design and production by closely coordinating the production engineers from both the factory and design sides. This coordination required sharing of knowledge for both sides, and Sony facilitated by exchanging personnel between the technical center and the production line. "Prototype making is always different from mass production, and the job of design engineers at the factory is to narrow the gap between the two. From the production side, on average, I made business trips [to the design division] three times per week" (Suyama, cited in Sony-EMCS 2004a). The production engineers from the factory side had two missions. First,

Source: Based on interviews by the author and Sony-EMCS (2005).

Figure 5. Map of Vaio 505 development: Japan (left), and an enlargement of the Tokyo area (right).

as stated, they had to confirm that what was specified by the design team would be produced on the production line. Additionally, they had to coordinate the production processes, including procurement of specialized parts from suppliers.

The higher level of miniaturization in the Vaio 505 meant that higher precision in locating components required a careful production process. This precision was particularly important for smaller components. The design engineer had to test the production line a few times to carefully confirm that the production line at the factory could produce exactly what the design team wanted (Miyano, interview, December 4, 2004). Excluding the design prototypes in the earlier concept development phase, the formal pilot production took place twice: once to test the mold making and the other to test mass production (Ito, interview, September 24, 2004).

As more configurations for software applications were needed, an additional 30 software engineers joined the Vaio team at the core location, Fujisawa. To incorporate the audiovisual dimension, the Vaio 505 contained graphics, map navigation, sound and multimedia audio programs, totaling 33 software programs (Sony 1997). The software engineers worked on the development, coordination, and adaptation of various programs. (Ito, interview, September 24, 2004).

Mass production started in October 1997, a month before the product was introduced to the market. By this stage, most of the design and software engineers at Fujisawa were no longer actively involved in the project, and the major players at this time were the production line in Nagano. The Nagano site produced both the Vaio laptops and the AIBO, a robot dog (Sony 2004c). There were 1,550 employees at this site, and about half of them were estimated to work in the production of various Vaio units.

There was collaboration with Sony's overseas R&D labs, from LSI Systems Lab of San Jose and Telecom Europe of Brussels. However, their role was limited to local adaptation, such as translations of brochures and labels, and configuration of software programs. The Vaio team decided that the model would be universal except the interface, and the local adaptation required only at the language level. Therefore, there was no extra role expected for overseas R&D labs.

The final intrafirm coordination took place between the design team and the marketing division. Since 1997, Sony had delegated the marketing function to its subsidiary, Sony Marketing, which was in charge of marketing and sales of all Sony products in Japan (Sony Marketing 2004). Ito, the project leader, presented the product concept and targeted consumers for the Vaio 505 to the marketing staff. Goto, the designer, explained the theme of the exterior design. This sharing of product image was critical in order for the sales staff to establish effective sales points.

After the initial release, the Vaio 505 captured 10 percent of the laptop market in Japan within two months. This was a significant share for just one model, i.e. not by the laptops of the company as a whole. Furthermore, it opened up a new market for laptops in non-office, household use and even in office use for style-conscious people. The ethos of portability and aesthetics was well received in the market. It thereafter created a competitive rush as other firms, such as Toshiba, IBM, and Matsushita developed this laptop market with their own style.

Analysis of the Process of Generating Innovation

This close-up analysis of innovation at the concrete, micro-level product development can provide insights into how the process of innovation is organized and how it is linked to a specific series of locations. This section synthesizes and discusses three features of the process of generating innovation based on Sony's Vaio case: complexity, the interdisciplinary development of technology, and prototyping and testing.

First, modern product development is about managing complexity. The Vaio 505 laptop consisted of about 1,100 components. A new product with new features came with new components, which could either be produced in-house, such as the magnesium exterior and the aerodynamic cooling method, or by suppliers, such as the LCD by Toshiba. In either case, it required a series of changes and innovations.

Moreover, it was not simply the number of components, but the coordination among them that made the product development process even more complex. The Vaio team developed many components simultaneously, yet had to make the new laptop function as a system. In such circumstances, the changes to components snowballed. The mechanical design engineers described the reconfiguration in the location of each component whenever a new material was introduced or changes to other components happened. Thus, this coordination and management was a lengthy and complex process.

Second, innovations often took place with an interdisciplinary approach. The best example was when the Vaio team faced limited space for the battery, on its face a matter of chemical engineering, and the issue was solved by a simple method proposed by the designer. Additionally, as the Vaio team decided to remove a cooling fan, an important mechanical component, they replaced this function by introducing new material from the field of chemical-physics and by configuring the most optimal thermodynamics via simulation technology. This shows that innovation did not necessarily happen in a single trajectory. In other words, higher technology was not necessarily better. An electrical engineering problem was not necessarily solved by gathering together more sophisticated electrical engineers. Solving the technical challenge was not easy, but could take place in multiple directions. Therefore, it was the availability, interaction, and management of several technical fields that shaped the new product. Sony had to manage a pool of highly skilled labor in electrical, mechanical, and simulation engineering as well as chemistry and physics. This interaction was most effectively possible at close proximity, so that the engineers and researchers could freely exchange, test, evaluate their knowledge, and recreate. In addition to the technical side, the development project as a whole incorporated the company's marketing division and also the executives. In an emergency, the understanding and support from the executive board was critical. Thus, coordination between various divisions of the company was essential.

Third, prototyping and testing was fundamental for the development of the laptop. Especially with this Vaio 505, it was not just a laptop meant to function with improved specifications, but a product with a new concept and a style. The product design in a digitized format presented by CAD on a computer screen hardly meant anything because the engineers had to evaluate what consumers would "feel" if the product was sitting next to them. This prototyping did not necessarily require the real laptop, but could be substituted with paper or polystyrene models. However, it was critical for all the core project members to be present with a prototype to discuss if it was "good-looking" or which model was better in what sense. The concept of portability set the weight limit, but this information of 1.35 kg (roughly 3 lbs.) was less relevant compared with carrying the real-size laptop with real weight to check if it was indeed portable and desirable. In sum, this prototyping and testing was a process that was space-constrained and required the physical presence of the product and of the core project members.

Conclusion

Through the micro–level case study of product development, this article has addressed the critical engineering and technical processes of making innovations that were tightly and inherently linked to a specific geography. By focusing on the three features of innovation examined here—complexity, interdisciplinary development, and prototyping—this study has demonstrated that the innovation associated with Sony's Vaio 505 laptop was a messy, lengthy, and unpredictable process. Furthermore, the engineering and technical features of innovation making were tightly located to the specific location. This new product was not the creation of one engineer who designed it from beginning to end. Rather, nobody knew what the final product would be at the beginning, and what was required was flexibility during the project. "Learning by doing" is a concept in organizational studies to encourage the creation of innovation (Young 1991; Irwin & Klenow 1994; Jovanovic & Nyarko 1996). The Vaio development case could more precisely be described as "learning only after making mistakes." In short, the product development is not a highly rationalized or centralized process, but an organic and interacting process. With this lengthy, complex coordination process, a firm had to prepare, ironically, for unplanned situations. The best solution was to have human and capital resources in proximity, and this was specifically why the colocation mattered.

While these findings provide new insight in economic geography, the results of this study also complement the three schools of thought discussed earlier. The study has observed the agglomeration linkages that exist between Sony and its suppliers. Social networks and face-to-face communication were important among the development team members when they discussed the meaning of the product concept and the stylishness of the most updated model. The process of prototyping and testing can particularly bridge the theory of tacit knowledge with innovation in a regional context. The concept of "portable and good-looking" came with a highly specific expectation of what was meant by "good-looking." At the same time, such understanding was not codifiable and was somewhat vaguely shared in the project members' minds from past experience and further elaborated in their discussions during the project. To discuss the understanding of "good-looking," the project members had to be co-located and they had to develop a prototype. That is why tacit knowledge is hard to transfer across distance.

Remote communications through information technology, conference calls, and videoconferencing played some role in the development process, but they did not become the main mode of coordination between project members. Ito, the project leader, stated, "we shared CAD (Computer Aided Design) in the Intranet, but that meant little in terms of development, but sharing the most updated design. When we tried to create new ideas, new design, or new something, we needed to meet and discuss" (Ito, interview, September 24, 2004). Findings from this research can further supplement such a statement. We have already discussed the example of the exterior design and the nuanced meanings of "stylishness." Moreover, when the communication became iterative, and several people were involved, remote communication technology was not an effective mode of communication. Other engineers expressed: "It [remote communication] just does not work" (Tambata, interview, September 24), or "That's not the way how things work" (Endo, interview, May 7, 2004). The engineers further pointed out that something would be missed via remote communication technology, which changed "the dynamics and richness of meeting" (Sakaguchi, interview, July 21, 2004).

For engineers, who had to create the best product, the most critical matter was how effectively they could reach the best solution. Whether it was possible to have a meeting via remote communication technology was of little concern. It might have been technically possible to exchange ideas via remote communication technology; if it would have been inefficient or taking a longer time to reach the solution, such communication was not desirable. To manage the complex project, engineers chose the most effective mode of communication, which in this case was the face-to-face meeting. In contrast, if the information flow was not needed to be iterative, remote communications could fill in the process in product development, such as to update the latest design or to provide notification of the conclusion of the previous meeting.

These findings differ from the past debates about innovation as an interactive process whose primary concern was how innovation occurred via technology-push, market-pull, or a mixture of both (Lundvall 1988; Lundvall 1992: Morgan 1997 p.493). Those studies further discussed the interaction among different economic players in a region, such as between firms, suppliers, and users. However, these interactions were still seen from the macro-perspective of innovation within a region. In contrast, the interacting process found in this research was a micro-level aspect within a product development project. Each stage and even each exchange of knowledge was interactive and shaped the course of the product and technological development.

It is important to consider how this particular case of geography of product development is situated among the global operations of Sony. Although this Vaio development presented only as one case among a number of Sony products, it provides a snapshot of the relationship between the main technical center in Tokyo and the overseas R&D centers. We have already observed that the role played by Sony's overseas R&D center in the Vaio 505's introduction was highly limited to the translation of brochures and labels. Additionally, the overseas R&D centers of Sony were substantially small in scale; each center usually had fewer than thirty engineers or researchers, sometimes only a few of them, while the main technical center had over two thousand (Endo, interview, May 7, 2004; Harryson 1998). Furthermore, with such small scale, each overseas R&D center was designed to develop only a specific and narrow technical field, such as the TV-video interface system in San Jose, California, a software application for CD-ROM in Singapore, and broadcasting equipment and systems in the UK (Arimura 1999). Other functions provided by the overseas R&D centers included minor local adaptations, such as modifying the electric voltage and changing colors and designs. Thus, there was little overlap and synergistic collaboration between the main technical center and the overseas centers, and the relationship between them was clearly hierarchical; the main technical center initiated the concept and led the major component development, and the overseas R&D centers contributed in the peripheral and the last-stage developments.

This study was an in-depth exercise to investigate the specificity of innovation. While the employed case study is an appropriate methodology for such analysis, we have to clarify what the case represents. In the past, Schumpeter (1926, p.66) provided an insight in providing a typology of innovations: (1) a new product, (2) a new market, (3) a new method of production, and (4) a new organization. The Vaio case represents the new product, more specifically in the R&D-intensive consumer electronics and computer sector. This article does not aim to generalize these findings to other types of innovations, and further study is needed in the other areas.

Second, we have to consider what the Sony case means more broadly. The objective of this project was to examine the engineering and technical aspects of innovation making through Sony, a Japanese firm, and not to argue that Japanese firms had specific geographic patterns of innovations. In this sense, this case was an appropriate sample among the leading players in the industrial field.

Third, we additionally need to consider how Sony behaved in comparison with other Japanese firms. Comparing Sony to the uniqueness of Japanese firms discussed by the past literature reveals that Sony did indeed behave like other Japanese firms. Sony had a life-time employment system. Although Sony was not affiliated with traditional keiretsu, the industrial conglomerates, Sony had its own networks of firms. Arita and Fujita (2001), and McCann and Arita (2006) found that Sony was typical of other semiconductor firms, like Toshiba, NEC, Mitsubishi, Fujitsu, Rohm, Oki, and Sanyo, where each core firm organized a vertically-integrated network structure. Therefore, the findings from this study provide direct implications at least for other Japanese firms. Moreover, despite these limitations in scope, this article can contribute as a first step to link the engineering and technical aspects of innovation-making and the location.

While most examples in this micro-level study were taken from in-house development, the findings can apply to the broader agglomeration at the metropolitan level. The tight and complex coordination would be required between firms, and hence, the proximity would be an enabling factor. Indeed, we observed examples of inter-firm coordination with Toshiba for the monitor and with a small supplier for the connector of the modem.

Lastly, it is important to note how this study framed the concept of a region. The past agglomeration school questioned why a specific region, say Tokyo or Silicon Valley, was important for a firm or a collection of firms. In contrast, this study questioned why proximity was important for a firm and its product development. In this sense, the approach to conceptualize a region was different, while the geographic coverage of both studies coincided at the same physical space, the Tokyo metropolitan region. The past agglomeration school perceived a region as an organic entity that produced innovations. In contrast, this study observed the proximity between the development center, the design center, and the headquarters, as well as the 'stickiness' between them (Markusen 1996, 2003), and concluded that a region was a place in which the stakeholders could maintain the tight and dense coordination between them. This coordination took place on a daily and ad-hoc basis to solve any number of problems that the stakeholders faced, and they executed such coordination within a metropolitan area.

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List of Interviewees

All interviews took place in Tokyo, Japan.

Aoki, Masayoshi. General manager. Corporate Headquarters. Sony. September 21, 2004.

Endo, Eishi, Ph.D. Assistant manager. Energy R&D Department. R&D Division. Energy Company, Sony. May 7, 2004.

Iguchi, Akira. Software leader. IT Company. Sony. December 4, 2004.

Ito, Susumu. Senior General Manager. VAIO Design Department. VAIO Design Division. Sony EMCS Corporation; Deputy General Manager. Departmnet No.2. IT Company. IT & Mobile Solutions network Company. Sony. September 21, 2004.

Katsumoto, Shuzo. Section Chief. Center for Environment Promotion. Sony. August 10, 2003; August 6, 2009.

Kurosawa, Nozomi. Assistant Manager. International Public Affairs. External Relations Department. Sony. July 21, 2004.

Miyano, Akihiro. Electrical designer. IT Company. Sony. December 4, 2004.

Sakaguchi, Kei. General Manager. Corporate PR Department. Corporate Communications. Sony. July 21, 2004.

Sanakata, Keita. Assistant Manager. Corporate PR Department. Corporate Communications. Sony. July 21, 2004.

Tambata, Ippei. Designer. HIGP. Design Center. Sony. September 24, 2004.

Toyoda, Mami. Human Resources Department 1. Sony. September 20, 2003.

Yokote, Hitomi. Senior Manager. International Public Affairs. External Relations Department. Sony. July 21, 2004.

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