Mobility of R&D Workers and Technological Performance*

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I. Introduction

If knowledge essential for innovation is assumed to be embodied partially in individuals, the "transfers" and "reassignments" engineers and researchers experience in society and among organizations can be surmised to affect the emergence of innovations. This reasoning springs from the fact transfers are linked with meeting new individuals, which in turn is thought to raise the probability of the knowledge integration necessary for innovation. Moreover, the probability of various technological information flowing to the sources of innovation increases if human networks are extended across organizations and departments by means of transfers. This also provides a rationale supporting the validity of the hypothesis that transfers encourage innovation.

Research to clarify the patterns of knowledge spillover that originate in R&D engineer transfers has been carried out based on such thinking as a premise (Almeida and Kogut 1999; Appleyard 1996). As the spill-over effects from a high level of worker mobility and unique local knowledge in a concentrated area—best exemplified by Silicon Valley—has been clarified since the 1990s in particular (Almeida and Kogut 1999; Angel 1989; Saxenian 1994), voices propounding the necessity of increasing R&D worker mobility as a factor to stimulate innovation have risen to a roar even in Japan. Arguments have been put forth linking the low degree of R&D worker mobility in Japan and the nation's economic slump since the 1990s, claiming there is a need to improve the mobility of specialized human resources in order to spur business recovery.

Certainly compared with the United States, the mobility of R&D workers

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in Japan can be said to be low (Lynn, Piehler and Kieler 1993; Shapira 1995; Appleyard 1996). On the other hand, however, interdepartmental transfers within organizations occur frequently in Japan—a fact that has been noted as one source of Japanese manufacturing competitiveness (Kusunoki and Numagami 1998). This is the argument that cross-functional integration required for new product development is being promoted effectively by the interdepartmental rotation of engineers. If the size of a firm is sufficiently large, transfers of workers across different functions and technical fields, in the sense of integrating different knowledge, offers the possibility of having the same effect as interorganizational transfers (Jervis 1975). Perhaps in response to such arguments, since the 1990s the tendency to reassign engineers and researchers to business divisions or manufacturing departments has increased even among the largest Japanese firms.[1] The fact R&D productivity was viewed as a problem at firms that were struggling due to depressed operating results following the collapse of the bubble economy is thought to be related to such human resource policies.[2]

Consequently, as the idea that engineer and researcher transfers promote innovation has become generally accepted, facilitating transfers has been recognized as an important issue for both government policy and corporate management. However, very little research exists which systematically verifies the hypothesis that R&D worker transfers promote innovation. Although both interorganizational transfers and intraorganizational transfers tend to be carried out as measures that will implicitly have a positive affect on innovation, this has not always been clarified empirically. Nor is such a result self-evident. Given such circumstances, the research reported here was conducted to empirically examine the relationship between interorganizational and intraorganizational transfers of engineers and researchers and technological performance, based on data concerning semiconductor engineers in Japan.

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1 This tendency is also shown clearly from the semiconductor engineer data analyzed for this research, which is described later in this paper. Engineers who joined companies in the 1980s and 1990s have experienced interdepartmental transfers more frequently than engineers who joined companies in earlier years, with early reassignment to manufacturing departments or business divisions being particularly remarkable.

2 There also is the aspect that as criticism of research activities not immediately related to earnings rose, researchers and engineers were reassigned to activities closer to business operations.

II. Existing Research Approach Concerning the Relationship between Engineers' Transfers and Performance

1. Interorganizational Transfers and Innovation Performance

The foundation of the thinking that R&D worker mobility between firms encourages innovation lies in the recognition that workers themselves are the most effective means of communicating important technological information. Much of the important information in the worlds of science and technology exists as tacit knowledge that has not been formalized (Kogut and Zander 1995; Cohen and Levinthal 1990; Von Hippel 1988). To transfer such knowledge, the human resources themselves that possess this knowledge must move.

Moreover, human resources who transfer to another firm bring with them more than just the technological knowledge they possess individually. The human networks formed in their previous workplaces also offer an important source of information for promoting innovation. As engineers with transfer experience can access external technological information that crosses organizational boundaries, such individuals can also be expected to fulfill a role as technological information "gatekeepers" (Allen 1977).

Appleyard (1996), for example, compared semiconductor design engineers in Japan and the U.S. It demonstrated that in contrast to a sample of Japanese engineers with no experience of mobility between firms and who relied on public information resources such as scientific publications and academic conference presentations, engineers in the United States who had more extensive transfer experience utilized engineers at other firms as an important information source. Similarly, Lynn, Piehler and Kieler (1993) demonstrated that compared with engineers in Japan, engineers in the United States with extensive transfer experience have more frequent contact with external specialists. This is because as it is conjectured that engineers moving among firms will engage in vigorous activities within their professional community to enhance their own market value, the knowledge obtained through their efforts is expected to produce a positive effect for the organization as well.

The formation of innovation in Silicon Valley, which attracted significant attention in the 1990s, is frequently explained indirectly by the knowledge spillover effect from frequent worker transfers (Angel 1989; Almeida and Kogut 1999; Saxenian 1994). For example, Almeida and Kogut (1999) surveyed the interfirm mobility of patent holders and frequency of patent citations, and clarified that in Silicon Valley there exist numerous mutual patent citations as well as large numbers of interfirm transfers of engineers in the region. This indicates the transfer of knowledge as a result of worker mobility within a region is linked to concentrations of innovation. Similarly, Angel (1989) also clarified the frequent transfers of human resources between universities and firms in the region, and highlighted the possibility of this phenomenon influencing the emergence of flexible manufacturing and innovation by analyzing the career histories of semiconductor production engineers in Silicon Valley. Nevertheless, such research has focused on clarifying the patterns of worker mobility based on the extent of innovative activities in Silicon Valley as a given. However, the research has not necessarily proven a causal relationship between worker mobility and innovation performance.

Consequently, while the research in recent years tends to assume a positive relationship between the interfirm mobility of engineers and innovation, there remains a sufficient probability that interfirm transfers do not stimulate innovation. It may be, for example, that engineers with interfirm transfer experience and who could become an important source of external technological information are not necessarily the most appropriate individuals from the standpoint of communicating external technological information within the organization. We cannot dismiss the possibility that, to the extent individuals who join an organization from another entity are treated within the organization as interlopers, intraorganizational communication problems might occur, or that individuals with little commitment to the organization might lack sufficient motivation to impart their knowledge. The danger of such problems occurring is thought to be especially great when organizational systems for evaluating, compensating and absorbing such engineers into the organization have not been established.

Ettlie (1980, 1985), who empirically studied the relationship between the inflow of new personnel and innovation activities, clarified that while inflows of new engineers have the effect of encouraging innovation, this relationship is not a monotonic increase. Based on a questionnaire survey of 56 food processing firms, Ettlie (1985) reported that a certain amount of external worker inflow has an innovation-stimulating effect, but that too large a personnel inflow oppositely exerts a negative influence on innovation.

2. Intraorganizational Mobility and Innovation Performance

Very little of the research literature addresses intraorganizational transfers of engineers directly from the standpoint of the effect on innovation activities. Rather, research that looks at intraorganizational transfers tends to focus on the influence such transfers have on the career formation of individuals. According to this research, intraorganizational transfers contribute to the acquisition of skills and accumulation of experience, and have a positive influence on promotions and upgrades in pay scale (see, for example, Campion, Cheraskin and Stevens [1994]). Such research also notes that intraorganizational transfers, in the sense that they are assignments to better responsibilities, have an uplifting affect on motivation and work attitudes (Campion, Cheraskin and Stevens [1994]; McElroy et al. [1996]). This research does not, however, clarify what affect such career formation through transfers has on an engineer’s innovation performance.

On the other hand, despite the fact that research focusing on technological development and new product development activity does not look directly at the effect of intraorganizational transfers, the research does offer important suggestions concerning the relationship between intraorganizational transfers and innovation (Allen 1977; Clark and Fujimoto 1991; Henderson and Cockburn 1994; Ancona and Caldwell 1992; Eisenhardt and Tabrizi 1995; Hansen 1999). Common to such research is the discovery that the sharing of knowledge or combinations of different information across organizational unit boundaries is vitally important for technological and product innovation. When knowledge sharing across departments is achieved by direct interdepartmental communications but the knowledge has a tacit, specific character, there is a danger communications costs will increase substantially due to the problem of differing interpretations of the information between departments (Hansen, 1999). In such cases, directly transferring engineers between departments is more effective (Allen 1977; Roberts 1988; Aoshima 2002; Kusunoki and Numagami 1998). Kusunoki and Numagami (1998), for example, analyzed data on personnel at Japan’s large chemical firms and discovered engineers are transferred frequently among departments; they argue that such transfers have the effect of promoting integration across functions and technical fields. Many case studies examining product development at Japanese firms also suggest that transferring engineers from the lab to an operating division or even the manufacturing department will promote product innovation.

Experience in various departments certainly might work effectively for commercializing technologies or turning them into a business. Moreover, utilizing experience gained in different departments is conceivable from the standpoint of fostering technological ideas as well. On the other hand, there is a danger frequent interdepartmental transfers will hinder the accumulation of expertise. This danger is particularly acute when transfers are made during the early stages of an individual's career as an engineer. On this point, the problem of the trade-offs arising from intraorganizational transfers is believed to be greater for technical human resources than in the case of administrative managers. Very little empirical research exists considering this point.

3. Interdependency between Interorganizational Transfers and Intraorganizational Transfers

As described above, until now research on interorganizational transfers and research on intraorganizational transfers have tended to be treated under separate traditions. Although both types of transfers have been compared in some international studies (see, for example, Lynn, Piehler and Kieler [1993]), there is no research clearly analyzing the mutual relationship between the two types of transfers. Should an interdependency exist between the two types of transfers, there is a possibility a simplistic approach aimed at encouraging innovation by improving mobility will not produce the anticipated results.

For any individual engineer, the fact that interorganizational transfers and intraorganizational transfers are mutually related is not simply because the number of transfers that can be achieved during one's entire career is limited. For example, as a result of emphasizing interaction with individuals outside the organization, an engineer who moves frequently between organizations might have a weak human network within the organization. This might lead to fewer in-house needs for that particular individual, which in turn could reduce opportunities for intraorganizational transfer (reassignment). There also is the possibility that possessing in-depth knowledge in a specific area of expertise will enhance an employee's value in the external labor market, while on the other hand making cross-functional transfers within the firm difficult. Being branded as the specialist in a specific area is also thought to create a sense of resistance to transfers within a firm.

The goal of this research is to clarify empirically the relationship between mobility and performance, while keeping in mind this mutual relationship between interorganizational and intraorganizational transfers.

III. Summary of the Analysis Data

1. Survey Summary

The data analyzed for this paper were obtained from a questionnaire survey distributed to 5,000 members of the Japan Society of Applied Physics.[3] The questionnaires were collected in January 1999, with valid responses obtained from 902 individuals. There were 749 respondents after excluding individuals with no experience at private sector firms and individuals who did not have experience in semiconductor-related businesses. Of these 749 respondents, individuals who had been at organizations other than a private corporation for 50% or more of their entire career were also excluded from the analysis. As a result, the entire sample consisted of 718 semiconductor engineers who had been employed mainly at private corporations. In addition to this entire sample, a separate sample, limited to engineers who were able to specify they had spent 50% or more of the years of their entire career in semiconductor-related design and development, was also used for the analysis. I will refer to this separate sample group as the R&D sample.

Respondents to the questionnaire survey were first asked to record their career during the period from 1965 to 1998 along a time line using eight factors, including the organization for which they worked, the region where they worked (geographic), the department to which they were assigned within the organization and the specialized area for which they were responsible. As a result, how the individuals had been transferred was understood for their entire careers by categories such as organization, geographic region, department within the organization and area of expertise. The data selected for analysis for this paper was mainly data concerning interorganizational transfers and interdepartmental transfers within an organization.

Next, respondents were asked to indicate the frequency of their communications with various individuals such as colleagues, engineers at other firms and university researchers, and to subjectively assess the importance of these individuals as a resource for problem solving.

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[3] Approximately 70-80% of the registered members of the Japan Society of Applied Physics are involved in semiconductor-related businesses.

Finally, respondents were asked to enter performance on the questionnaire form. As technological performance, respondents were asked to indicate the number of patents applied for and the number of papers published outside of those in professional journals up to that point. Respondents also were requested to subjectively evaluate the degree of satisfaction with their capabilities as researchers and engineers, the speed of their promotions, and their current work. Although both individual performance and performance as a group or organization are necessary in order to measure innovation results, comparable indicators of performance at the group level were unobtainable because the respondents belonged to various firms.

Table 1 shows a summary of the sample. When transfers to affiliated firms such as subsidiaries are excluded, overall about 29% of the respondents have experienced at least one interorganizational transfer.[4] However, the percentage drops to 17% when limited to only mobility between private firms. About 15% of the respondents had earned a doctorate. Considering that nearly 70% of all respondents had an advanced degree when those with a masters degree are included, this sample is thought to include not only engineers but also many workers whose job responsibilities are close to those of a researcher. Also, the fact that many transfers between firms and universities are observed, or that more than 10% of the respondents are engaged in basic research, is believed to be a manifestation of this.

2. Variables

There were many variables included in the analysis, which were roughly classified into mobility-related variables, communications and information source-related variables, and performance-related variables. In addition, depending on the analysis, control variables were introduced.

Interorganizational transfers were measured using the number of organizations at which respondents had worked as of the survey date. However, seconding to another company or transfers to an affiliate or a subsidiary were

[4] This could be regarded as a problem of response bias, in which respondents answered as individuals having transfer experience because of the content of the questionnaire; however, the result of this sample, in which 29% had transfer experience, is consistent with the survey results in Lynn, Piehler and Kieler (1993), in which 26% of the respondents had transfer experience. Therefore, response bias does not appear to be a major problem.

Table 1. Sample summary

	Age	Service period	Patents applied	Papers published
Mean	43.7	18.9	17.2	41.4
Standard deviation	9.7	9.5	59.3	39.3

Education completed					
High school	Technical school	Bachelor's	Master's	Doctorate	Unknown
7	3	183	379	105	41
1.0%	0.4%	25.5%	52.8%	14.6%	5.7%
Year entered company					
1960s	1970s	1980s	1990s	Unknown	
151	201	296	101	3	
21.0%	28.0%	41.2%	14.1%	0.4%	
Number of organizations (*Excluding affiliated companies*)					
1 company	2 companies	3 companies	4 companies	5 or more companies	Unknown
445	167	57	24	21	4
62.0%	23.3%	7.9%	3.3%	2.9%	0.6%
510	*132*	*42*	*17*	*13*	*0*
71.0%	*18.4%*	*5.8%*	*2.4%*	*1.8%*	*0.0%*
Main area of specialization (>50% of entire career)					
Basic research	Device development and design	Process development	Materials development	Systems development	Testing and evaluation
80	60	136	54	3	21
CAD/CAE	Equipment development	Other development	Quality control	Manufactur -ing	Planning
4	37	13	3	9	1
Marketing	Other manufactur -ing or sales	Application products	Other	Unknown	
1	1	45	88	162	

excluded from the organizations where respondents had worked.

Intraorganizational transfers were measured by the number of departments to which the respondents had been assigned until the time of the survey, with respondents selecting from among a total of nine departments. These included corporate research departments (labs), corporate development departments, corporate production technology departments, divisional research departments, divisional development departments, divisional production technology departments, factories or manufacturing departments, planning and control departments, and sales and marketing departments. The mean number of departments at which respondents had work experience was 2.11 departments; the standard deviation was 1.31. Furthermore, for individuals who had at least one interdepartmental transfer experience, the number of years they were employed until their initial interdepartmental transfer was included in the analysis. The mean was 9.03 years, with a standard deviation of 6.51 years.

The frequency of communications with 12 categories of individuals, such as colleagues in the same workplace, engineers in other departments of the company, engineers at competitor firms and university researchers, was measured using a seven-point scale for frequency of communications, ranging from 1: "Once a year or less" to 7: "Almost daily." In addition, respondents were asked to subjectively evaluate 21 categories of information sources consisting of these 12 categories of individuals, as well as sources such as academic associations and professional journals, as sources of problem-solving information using a seven-point scale ranging from 1: "Not important at all" to 7: "Extremely important" (these communication and information source items are shown in Appendix Table 1).

Technological performance was measured using the number of patent applications and number of papers published in professional journals. Respondents were asked to indicate on the questionnaire form the actual number of their patent applications and number of papers published, separated among three periods covering the past five years, from five years ago to ten years ago and more than ten years ago. In the analysis below, the values for the number of patents and number of papers, respectively, are the simple totals of the figures for the three periods of each category.

The respondents also compared their capabilities as researchers and engineers and the speed of their promotions with those of their colleagues by subjectively evaluating these items using a seven-point scale ranging from 1: "Completely inferior" to 7: "Extremely superior." The mean values for the entire sample were 5.02 (capabilities) and 4.08 (speed of promotions); the standard deviation was 1.14 and 1.33, respectively. Respondents were also asked to subjectively evaluate the level of satisfaction towards their work using a seven-point scale ranging from 1: "Completely dissatisfied" to 7: "Very satisfied." The mean value and standard deviation were 4.32 and 1.58, respectively.

Table 2. Frequency of transfers and technological performance

	Number of patents held				Number of papers published			
	Entire sample		R&D sample		Entire sample		R&D sample	
Service years	0.44	***	0.40	***	0.33	***	0.35	***
Number of experienced organizations	-0.11	***	-0.07	*	-0.09	**	-0.03	
Number of experienced departments	-0.07	**	-0.04		-0.13	***	-0.09	*
Adjusted R^2	0.14	***	0.14	***	0.08	***	0.12	***
Degrees of freedom	684		425		684		401	

OLS. *p<.1, **p<.5, ***p<.01.

The correlation matrix between the transfer variables and performance variables is indicated in Appendix Table 2.

IV. Results of Analysis: Relationships between Transfers and Performance

1. Transfer Frequency and Technological Performance

Table 2 shows the results of a regression analysis concerning the relationship between transfer frequency and technological performance. As both the number of patent applications and number of papers are thought to increase with time, service years have been introduced as a control variable to show the elapsed years since being first employed until the time of the survey.

The analysis of the entire sample shows both interorganizational transfers and intraorganizational transfers have a significant negative relationship with technological performance. There is a possibility that part of this result stems from the fact individuals for whom technological performance in the form of patents and papers are not a direct goal are included in the sample, and that such individuals have experienced frequent interorganizational and intraorganizational transfers. The sample includes individuals involved in the development of application products that use semiconductors rather than in the development of semiconductors themselves. These individuals are working in areas close to commercialization, and publication of papers may not be a required output for them. Therefore, the results from a similar analysis, performed after extracting as the R&D sample only those respondents who were able to specify they had spent 50% or more of their entire career in semiconductor design and development activities, is likewise described in Table 2.[5] As a result, the negative effect transfers have on technological performance is certainly reduced. However, such a result notwithstanding, there is still a negative relationship. The main objective of the analysis described below in Section V was to search for the logic behind this discovery, which seemingly contradicts our ordinal intuition.

2. Transfer Frequency and Speed of Promotions, Capabilities and Degree of Satisfaction

On the other hand, Table 3 shows the results of an analysis for the relationship between transfer frequency, and a subjective evaluation of speed of promotions, technical capabilities and degree of satisfaction. A statistically significant relationship was found between intraorganizational transfers and speed of promotions, and between interorganizational transfers and degree of satisfaction. This result, which suggests intraorganizational transfers have a positive influence on the speed of promotions, is consistent with the findings of the existing research. Nevertheless, because it is not possible in this research to distinguish between interdepartmental transfers accompanying a promotion and pure rotations, the possibility remains that individuals who are promoted have experience working in many departments as a result. On the other hand, the result that individuals who have transferred between organizations indicated a low degree of satisfaction with their current work might suggest that workers who transfer between firms are not always necessarily assigned to an appropriate place within their new organization. These findings will be studied again when the cause of the negative relationship found between transfers and technological performance is investigated.

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[5] The main reason for the large decrease in the sample number is that the main activity area could not be identified for some individuals. This is because part of the entries for activity areas were not completed, rather than because individuals engaged mainly in semiconductor-related design and development activities were too few in the original sample. There were 162 individuals for whom their main activity area could not be specified.

Table 3. Frequency of transfers, speed of promotions, capabilities as a researcher and engineer, and degree of satisfaction with current work

	Speed of promotions		Capabilities as a researcher and engineer		Degree of satisfaction with work	
	Entire sample	R&D sample	Entire sample	R&D sample	Entire sample	R&D sample
Service years	-0.00	-0.00	0.03 ***	0.04 ***	0.03 **	0.02
Number of experienced organizations	-0.07	-0.07	0.02	-0.04	-0.07	-0.18
Number of experienced departments	0.15 ***	0.18 **	0.02	0.01	-0.01	-0.01
– 2 log likelihood	1543.3	1014.3	1296.4	877.4	1605.1	1089.0

Ordinal regression analysis (PLUM). *p<.1, **p<.5, ***p<.01.

V. Causes of the Negative Relationship Found between Intraorganizational Transfers and Technological Performance

Table 2 implies that intraorganizational transfers (interdepartmental rotations) might have a negative affect on the performance of engineers. What could cause such a result?

Intraorganizational transfers help create human networks across departments, while simultaneously increasing engineers' exposure to different knowledge. This produces the knowledge integration believed to be necessary for innovation. Such linkage has come to be regarded as the logic explaining the encouragement of innovation through intraorganizational transfers. Therefore, if we assume intraorganizational transfers have a negative impact on technological performance, there is a possibility the human networks within organizations are not functioning well or that intraorganizational transfers hinder access to important external technological information. The analysis in Table 3 was undertaken to confirm this conjecture. Table 4 shows the result of a regression analysis of the effect intraorganizational transfers have on human communications inside and outside an organization, and the factors emphasized by engineers with intraorganizational transfer experience as information sources for problem solving. Since information sources were considered to increase with each year passed, service years were controlled in the analysis. Only items for which a statistically significant result was obtained are shown in Table 4.

Table 4. Intraorganizational transfers, communications, and important information sources for problem solving

Dependent variable	Research and development sample
Frequency of communication	
Departments where previously worked for within the organization	*
University researchers	*** (-)
Information sources for problem solving	
Same area of specialization outside of the company	* (-)
University researchers	*** (-)
National research institutes etc.	** (-)
University (graduate school) friends and acquaintances outside of the company	* (-)
Professors when enrolled in university	** (-)
Business consultants	**

Ordinal regression analysis (PLUM). *p<.1, **p<.5, ***p<.01.
Independent variable: Number of experienced departments.
Control variable: Number of service years.

From Table 4, a relationship can be perceived in which individuals have less access to external information as they experience frequent intraorganizational transfers. On the other hand, despite the fact that there are extensive interactions with individuals in departments where a respondent had been assigned previously due to intraorganizational transfers becoming more frequent, no tendency to use individuals in other internal departments as an important source for problem solving was found. In other words, individuals with frequent interdepartmental transfers within an organization are cut off from external technological information, yet at the same time cannot take sufficient advantage of their in-house human network stretching across departments. Such circumstances are thought to be one reason why intraorganizational transfers are not related to the performance of engineers.[6]

[6] The possibility that individuals given frequent intraorganizational transfers are engaged in administrator activities cannot be completely denied. However, such a possibility is not considered to be high because a negative relationship is found even for the sample limited to research and development, and because the service years are controlled.

Table 5. Effect of number of years in the first assignment on technological performance

	Number of patents held		Number of papers published	
	Entire sample	R&D sample	Entire sample	R&D sample
Service years	0.16 ***	0.23 ***	0.11 *	0.19 **
Number of experienced organizations	-0.02	-0.02	-0.02	0.01
Number of experienced departments	0.04	-0.05	0.01	0.00
Number of years in initial department	0.24 ***	0.20 ***	0.18 ***	0.13 *
Adjusted R^2	0.12 ***	0.12 ***	0.06 ***	0.07 **
Degrees of freedom	451	280	451	263

OLS. *p<.1, **p<.5, ***p<.01.

The possibility that frequent interdepartmental transfers hinder the development of expertise can also be contemplated as another cause. In the case of engineers and researchers working for Japanese firms in particular, sufficient time to establish a specialty in the early stages of one's career is considered necessary. This is because in many cases the area of specialization at a university is not connected directly to an individual's area of specialization at a firm. Accordingly, transferring to another department too soon after joining a company might have a negative influence on later technological performance. To confirm this, the sample was limited to only those respondents with at least one intraorganizational transfer, and the effect the number of years until the first interdepartmental transfer had on technological performance was analyzed. Table 5 shows the results.

The result supports the prediction; a significant positive relationship was found between the number of years in a position until the first interdepartmental transfer, and the number of patents and number of papers. Moreover, the negative effect of interorganizational transfers and intraorganizational transfers on performance was extinguished by introducing the number of years individuals spent in their initial position. As intraorganizational transfers have a significant negative relationship with the number of years until the first interdepartmental transfer, the negative effect that intraorganizational transfers have on performance is thought to be explained by the short length of assignment in the first department. Such a result suggests that it is early transfers that caused problems by hindering the accumulation of expertise, rather than the issue of interorganizational transfers themselves.

Against this result, however, the hypothesis that individuals with low technological performance should be pushed out to another department at an early stage as unnecessary staff has also been sufficiently raised. As the causal direction cannot be specified here, which hypothesis is correct cannot be determined. However, in research in the United States which analyzed personnel data for specific firms, it was reported that the greater an individual's performance the higher the tendency to receive job rotations (Campion, Cheraskin and Stevens 1994). This indicated that transfers to a better position can be used as one way of rewarding employees. Which status applies in the case of Japanese firms is a topic for future research.

VI. Cause of the Negative Relationship Found between Interorganizational Transfers and Technological Performance

In recent years, the idea that engineer mobility encourages innovation has become accepted thinking. In addition, existing research tended to assume innovation promoting effects of technological knowledge spillover driven by the transfer of engineers. Nevertheless, the research reported here suggests interorganizational transfers are not necessarily linked merely to excellent technological performance, at least when viewed at the individual engineer's level, and indeed can have a negative influence on performance. What causes such a result?

One reason interorganizational transfers of engineers are thought to promote innovation is the belief that engineer mobility enables transfers of tacit knowledge. Moreover, the external human network produced within the organization following an inflow of engineers facilitates access to vital technological knowledge existing outside the organization, which in turn sets the stage for the ensuing effective integration of internal and external technological knowledge to become another factor promoting innovation.

However, to effectively integrate the knowledge introduced by engineers transferred between organizations with an organization's internal knowledge, the engineers who are transferred must be skillfully incorporated into the organization's internal human network. It is believed that interorganizational

Table 6. Interorganizational transfers, communications, and important information sources

Dependent variable	R&D sample
Frequency of communication	
Colleagues in the same workplace	** (-)
Same area of specialization outside of the company	**
Different areas of specialization outside of the company	**
Acquaintances from university years outside of the company	**
Professors when enrolled in university (graduate school)	**
Information sources	
Workplace colleagues	*** (-)
Engineers and researchers in other departments within the company	*** (-)
Workplace superiors	*** (-)
Departments where previously worked for within the firm	** (-)
Competitors	* (-)
Internal study seminars	*** (-)

Ordinal regression analysis (PLUM). *p<.1, **p<.5, ***p<.01.
Independent variable: Number of experienced organizations.
Control variable: Number of service years.

transfers will not necessarily improve technological performance if frequent transfers between organizations result in weak personal ties within the organization, or make access to technological knowledge within the organization difficult. Table 6 highlights results confirming this aspect.

Table 6 shows the results from analyzing the effect interorganizational transfers have on communications with individuals inside and outside the organization, and the effect interorganizational transfer experience has on information sources considered important for problem solving. As in Table 4, only the items for which a statistically significant result was obtained have been described.

As indicated in Table 6, there is a propensity toward more frequent communications with engineers outside the company as the number of interorganizational transfers increases. This is consistent with the general prediction. Notwithstanding this result, however, no tendency is seen in the use of these engineers outside the company as an important information source for problem solving. On the other hand, engineers who have made interorganizational transfers have fewer opportunities for communication with their colleagues at work, and do not utilize other engineers or their superiors within the organization as important sources of information for problem solving. In this respect, engineers who make interorganizational transfers have the opposite characteristics of engineers with intraorganizational transfer experience. In fact, interorganizational transfers and intraorganizational transfers have a significant negative correlation. [7] In other words, circumstances can be envisioned in which engineers who transfer between organizations maintain their external network of contacts, but tend to be shut out from the human and informational networks within the organization; consequently, the organization does not gain opportunities to sufficiently utilize the information obtained from outside. The result in which interorganizational transfers have a negative effect on technological performance is thought, in one sense, to reflect such conditions.

Moreover, there is a possibility that the inability of engineers who have transferred from another organization to achieve sufficient technological performance is also influenced by personnel assignment-related or compensation-related issues. One reason for the result shown in Table 3, in which the level of satisfaction with one's current workplace is low given more frequent interorganizational transfers, might be that such individuals are not being assigned to an appropriate workplace in the organization.

Moreover, as can be seen in the same Table 3, the fact that the speed of promotions is faster for individuals with frequent intraorganizational transfers could also be a factor lowering the motivation of individuals who transfer between organizations. To look at this aspect in slightly sharper detail, the results from studying how communication patterns or methods of using information sources within an organization exert a positive influence on the speed of promotions are shown in Table 7. According to this analysis, when it comes to communications, both frequent interaction with other internal human resources, whether colleagues, engineers in other departments in the organization, or engineers in departments where one was previously assigned within the organization, and interaction with external human resources, including engineers in the same area of specialization who work outside the

[7] The partial correlation with service years controlled is -0.20, and it is significant at the 1% level.

Table 7. Speed of promotions, communication patterns, and important information sources

Independent variable	Research and development sample
Frequency of communication	
Colleagues in the same workplace	*
Engineers and researchers in other departments within the company	**
Departments where previously worked for within the firm	***
Same area of specialization outside of the company	**
University researchers	**
National research institutes	*
Professors when enrolled in university (graduate school)	*
Information sources	
Workplace colleagues	***
Engineers and researchers in other departments within the company	***
Managers in other departments within the company	***
Workplace superiors	***
Professors when enrolled in university (graduate school)	*
Electronics journals	**

Ordinal regression analysis. *p<.1, **p<.5, ***p<.01.
Dependent variable: Speed of promotion.
Control variable: Number of service years.

organization, university researchers, and one's professors when in college, have a positive relationship to the speed of promotions. However, as for a source of problem solving information, the extent to which individuals emphasize internal human resources, such as workplace colleagues, superiors, and engineers and administrators in other internal departments, results in faster promotions. Consequently, given the current situation in which informational ties with personnel within an organization are linked to compensation in this manner, there is a possibility that personnel who have transferred in from outside the organization are not being evaluated sufficiently and thus lose their motivation.

If the creation of human or informational networks within an organization in this manner is important from the standpoint of compensation, competent technical professionals may hesitate to move across organizations. Therefore, there is a possibility that the negative relationship between interorganizational

Table 8. Correlation between transfers and number of experienced areas

	Interorganizational transfers	Interdepartmental transfers	Number of specialized area experiences	Number of product area experiences	Number of application area experiences
Interorganizational transfers		-0.20***	0.04	0.09*	0.06
Interdepartmental transfers			0.16***	0.10**	0.05
Number of specialized area experiences				0.38***	0.30***
Number of product area experiences					0.46***
Number of application area experiences					

R&D sample.
Numeric values in the table are a partial correlation. *p<.1, **p<.5, ***p<.01.
Control variable: Service years.
Specialized areas of experience: Basic research; device development and design; process development; materials development; systems development; testing, evaluation and simulations; CAD/CAE tools; equipment development; other semiconductor development; quality control; manufacturing and mounting; planning; marketing; applications using semiconductors.
Product areas of experience: Memories; MOS micro; logic; analog IC; discrete semiconductors; other semiconductors; applications using semiconductors.

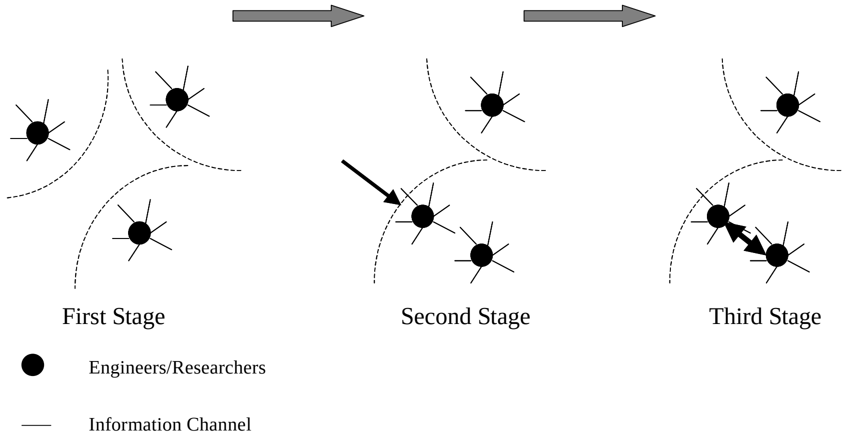
transfers and technological performance indicates that only engineers with low performance are being transferred between organizations. Data to directly confirm this point is not available, but we have some related information. When limited to the sample reported here at least, engineers who frequently make interorganizational transfers appear to not be engineers who specialize in a specific area of expertise. Table 8 highlights this indirectly, showing the relationship between specialized areas or semiconductor product areas experienced and interorganizational or intraorganizational transfers. As predicted, frequent intraorganizational transfers have a positive relationship with the number of specialized areas or semiconductor product areas experienced. On the other hand, engineers who make interorganizational transfers are not limited to one specialized area and indeed tend to have experience in semiconductor product areas more than others. In addition, the negative correlation between the ratio of specialization in a specific area of expertise (period of longest experience in a specialized area/period of entire career) and number of organizations experienced (Kendall tau coefficient = –0.09, $p<.05$) also shows that engineers who transfer between organizations are not necessarily highly specialized human resources.

VII. Discussion

Although the idea that engineer mobility promotes innovation has become generally accepted, the research reported here showed that there is instead a negative relationship between interorganizational and intraorganizational transfers of engineers and technological performance. This finding, however, does not necessarily mean engineer mobility is unnecessary for innovation. If there are defects somewhere in the entire innovation process mediated through engineer transfers, it is possible the effects of the transfers cannot be observed.

The creation of innovations through human transfers can be understood according to three stages (Figure 1). In the first stage, engineers accumulate specialized knowledge while simultaneously forming their own human networks within the broad system of division of labor including the firm's organization. These human networks become the unique information channels necessary for obtaining information for technological development. In the second stage, engineers change the place of their technological development activities, which include the organizations to which they belong or their departments and regions. This leads to the transfer of the locations of the knowledge and information channels associated with each engineer, creating new opportunities for integrating technical knowledge. The possibilities for new combinations of knowledge will especially increase when engineers possess unique technical knowledge that is difficult to codify and document in writing. In the third stage, transferred individuals engage in direct interaction with engineers in the places to which they have transferred. The unique knowledge possessed by the transferred individuals, along with the external information that flows in through the transferred individuals' information

Figure 1. Combination of knowledge by people transfer



channels, is brought to the workplace where the new knowledge is integrated and innovations are created.

This research suggests the failure of interorganizational transfers to be linked to engineers' performance is mainly a problem at the third stage. Although transferred individuals possessed information channels outside the organization, the information obtained through these channels was not being utilized for actual problem-solving activities. For the integration of knowledge obtained through transfers to occur, transferred engineers must be incorporated into the human networks of the organization they have joined. They must also be given opportunities to actively disclose their unique knowledge and the external information obtained through their own information channels. However, there was a propensity for transferred engineers to be shut off from the human network within the organization and have insufficient interaction with other individuals in the organization, and to face limited access to internal information sources. In addition, given an environment in which promotions are faster for engineers who are well versed in internal information sources, a decrease in motivation was predicted. These circumstances were indicated by the results, which show a lower level of satisfaction among transferred engineers in their current work.

On the other hand, the fact intraorganizational transfers are not related to technological performance appears to be a problem particularly at the first of the three stages. In particular, the result indicating technical engineers who experience interdepartmental transfers early in the initial stage of their career have lower levels of performance suggests the possibility that such transfers interfere with the establishment of a special area of expertise and formation of an important human network in the area of expertise. In other words, the problem is thought not to be the organizational transfers themselves, but rather some problem in the expertise acquisition stage before the transfer. Moreover, this research suggests a problem in the third stage as well. Individuals who are transferred frequently between departments do not always use human networks they've developed in earlier assignments as an important information source. Such an outcome is conjectured to occur because personnel rotations are not being accomplished in a form that enables engineers to take maximum advantage of their past experience.

Consequently, appropriate organizational management is thought to be critical for linking both interorganizational transfers and intraorganizational transfers to technological performance. For interorganizational transfers, a process to integrate transferred engineers into the internal human network is vital; personnel assignments that enable organizations to take advantage of the knowledge and external information channels possessed by transferred individuals along with compensation systems to evaluate such knowledge and information channels are also thought to be necessary.

For intraorganizational transfers, on the other hand, it is important to think about the timing of transfers to ensure that they do not interfere with the accumulation of expertise by engineers or the formation of broad human networks in specialized fields. Giving consideration to transfer positions that can take maximum advantage of the experience and human networks accumulated by engineers prior to their transfers is also important.

In addition, the findings of this research indicating a negative relationship between interorganizational transfers and intraorganizational transfers, and the quite different characteristics of individuals transferred between organizations and individuals transferred within an organization, highlight a separate management issue concerning the balance between hiring specialized workers from the outside and the rotation of internal personnel.

There are naturally various limitations on this research. Interpretation of the causal relation in particular is a problem. First, for both intraorganizational transfers and interorganizational transfers, there is believed to be a causal relationship in the opposite direction in which engineers with low performance are transferred by necessity. However, for interorganizational transfers there also is a possibility that capable specialists are missing transfer opportunities because of management problems, whether pertaining to assignments of transferred individuals within the organization or compensation. In such instances, management needs to be reformed.

Appendix Table 1. Communication counterparts and important information sources for problem solving

Communication counterparts

- Colleagues in the same workplace
- Engineers and researchers in other departments within the company
- Engineers and researchers in organizations where previously employed
- Engineers and researchers in workplaces where previously worked for within the company
- Engineers and researchers in the same area of specialization outside the company
- Engineers and researchers in different areas of specialization outside the company
- Engineers and researchers at competitor firms
- Engineers and researchers at partner firms
- University researchers
- Researchers at non-profit institutions such as national research institutes
- Acquaintances from years at a university (graduate school) outside the company
- Professors when studying at a university (graduate school)

Information sources

- Colleagues in the same workplace
- Engineers and researchers in other departments within the company
- Administrators of other departments within the company
- Workplace superiors
- Engineers and researchers in the same area of specialization outside the company
- Engineers and researchers at organizations where previously employed
- Engineers and researchers in workplaces where previously worked for within the company
- Engineers and researchers at competitor firms
- Engineers and researchers at partner firms
- University researchers
- Researchers at non-profit institutions such as national research institutes
- Acquaintances from years at a university (graduate school) outside the company
- Professors when studying at a university (graduate school)
- Business consultants
- Academic associations
- Journals, science papers, professional literature
- Electronics journals
- Information delivered over the Internet
- Patents
- In-house training and seminars
- Training and seminars outside the company

Appendix Table 2. Correlation matrix among variables

	Interorganizational transfers	Intraorganizational transfers	Years until initial transfer within organization	Number of patents held	Number of papers published	Capabilities as an engineer and researcher	Speed of promotions	Level of satisfaction with current work	Years in present position
Interorganizational transfers		-0.02 -0.05	-0.10* -0.05	0.02 0.06	0.06 0.09	0.06 0.04	-0.03 -0.02	0.02 -0.05	0.32** 0.32**
Intraorganizational transfers			-0.16** -0.12*	0.10* 0.15**	-0.02 0.05	0.08* 0.08	0.09* 0.11*	0.05 0.03	0.36** 0.39**
Years until initial transfer within organization				0.30** 0.31**	0.23** 0.21**	0.05 -0.01	0.01 -0.00	0.00 -0.08	0.42** 0.45**
Number of patents held					0.34** 0.31**	0.24** 0.22**	0.05 0.02	0.11** 0.08	0.33** 0.35**
Number of papers published						0.22** 0.24**	0.16** 0.20**	0.12** 0.13**	0.23** 0.30**
Capabilities as an engineer and researcher							0.27** 0.21**	0.15** 0.16**	0.12** 0.16**
Speed of promotions								0.33** 0.31**	0.01 0.04
Level of satisfaction with current work									0.13** 0.07
Years in present position									

Simple correlation, Pairwise deletion. Two-tailed test. *<.05, **<.01.
Upper values: Entire sample; Lower values: Research and development sample.

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