The Labor Market for Japanese Scientists and Engineers: Is the Labor Market Externalized? What Has Happened at Their Workplace?

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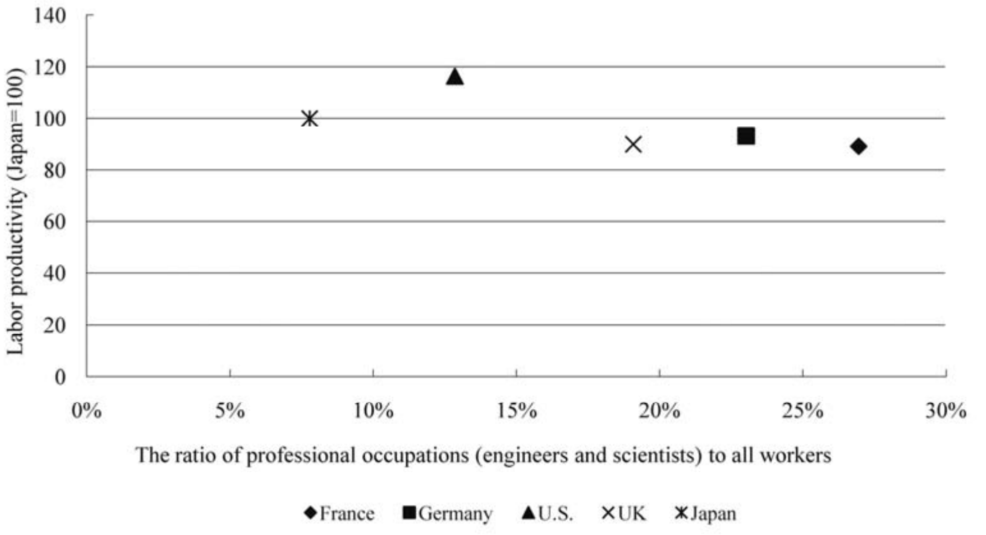
In recent years, the management of Japanese companies has been responding to changes in the surrounding business environment characterized by increasing and inevitable globalization.[1] Amongst such changes, attracting particular interest are those in human resource management. This is because the human resources are the most difficult among various management resources to move across borders, and as a result the management of human resources is strongly influenced by their respective regional social conventions and culture and thus varies substantially across regions. From that standpoint, a country's readiness for globalization may be measured by changes in the management of human resources. Can a change be seen in the commitment to long-term employment and of the promote-from-within policy that have featured the human resource management of Japanese companies for a long time? Of the corporate professions, scientists and engineers are the occupations in which standardization of jobs and a switch to an external labor market are considered to be the easiest. This paper explores how such "externalization" progressed in their employment, how the human resource management of companies has changed in relation to them, and what kind of changes can be observed regarding these groups' perception of their job and company accordingly.

I. Introduction: The Current State of Japanese Scientists and Engineers

What image do we have of Japanese scientists and engineers? Many are said to have the general characteristics of the Japanese people—there is an impression that they have positive qualities such as diligence, patience and strong loyalty to their company. Here we would like to share with our readers interesting data, not popular images, concerning them. It is data relating to the Japanese manufacturing industry's labor productivity and the share of the scientists and engineers among its manufacturing workers. Labor productivity is the total economic value created by a company or a country divided by the total number of workers involved in its production. Essentially, it is an index representing how much economic value is produced by one worker by looking at the average. When this index is applied to the manufacturing industry, it becomes an indicator for the creation of economic value of the country's manufacturing workers.

In Figure 1, the vertical axis indicates the manufacturing labor productivity of each

[1] Some of the recent works on this topic include 2007 special issue of *Asian Business and Management* and Miyoshi and Nakata (2011).



Source: ILO LABORSTA and OECD National Account.

Figure 1. International Comparison of the Ratio of Professional Occupations and Labor Productivity in the Manufacturing Industry (2005)

country and the horizontal axis represents the ratio of scientists and engineers that comprise the total persons engaged in manufacturing in each country.[2] From this, we can see that the labor productivity of Japanese manufacturing workers is slightly inferior to that of their U.S. counterparts; however it surpasses that of the workers employed in the German, English and French manufacturing industries and shows that they are creators of high economic value. An important point to note is that the Japanese manufacturing industry achieved this high labor productivity with the lowest proportion of scientists and engineers of the five countries compared (left-most position in the chart). From the chart we can see that the favorably compared labor productivity of the Japanese manufacturing industry is achieved with a proportion of scientists and engineers about half of that of the U.S., which has the highest labor productivity.

How is it possible for Japan's manufacturing industry to achieve such labor productivity with so few engineers? We will find an answer for this question as we proceed with our inquiry, but first let's review the features of both the quality and quantity of Japanese scientists and engineers and take a look at the current situation.

[2] The only internationally comparable data available from the ILO was that of a wide range of professional job classifications in which technicians were included. However, because almost all of the professional jobs in the manufacturing industry are comprised of scientists and technicians, it was used as a substitute index.

Table 1. Changes in the Nnumber of Natural Scientists, Engineers and All Other Workers

(A) All industries

Year	All other workers	*Index*	Natural scientists and engineers			
			Total	*Index*	Engineers	Natural scientists
1980	55,778,234	*100*	937,871	*100*	874,142	63,729
1985	58,336,129	*105*	1,824,045	*194*	1,729,536	94,509
1990	61,679,338	*111*	2,218,603	*237*	2,108,239	110,364
1995	**64,181,893**	***115***	2,537,927	*271*	2,370,303	**167,624**
2000	63,032,271	*113*	**2,676,227**	***285***	**2,523,885**	152,342
2005	61,530,202	*110*	2,283,097	*243*	2,140,612	142,485

(B) Manufacturing industry

Year	All other workers	*Index*	Natural scientists and engineers			
			Total	*Index*	Engineers	Natural scientists
1980	13,041,563	*100*	258,404	*100*	246,692	11,712
1985	13,837,254	*106*	617,195	*239*	593,979	23,216
1990	**14,502,665**	***111***	643,056	*249*	621,076	21,980
1995	13,374,189	*103*	**668,915**	***259***	**625,329**	**43,586**
2000	12,202,064	*94*	657,603	*254*	618,804	38,799
2005	10,485,635	*80*	602,396	*233*	569,666	32,730

Source: Population Census (Statistics Bureau of MIC).

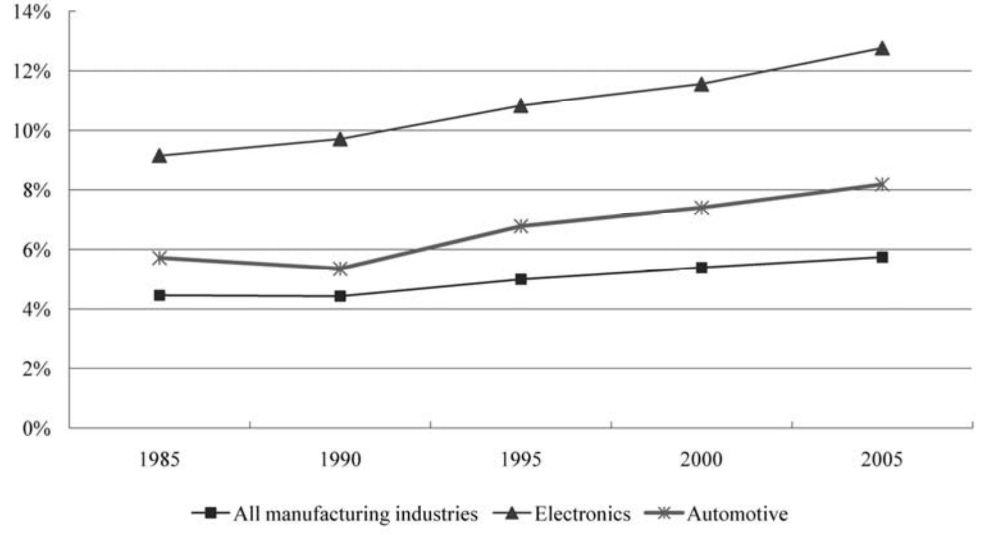
1. Quantitative Features of Japan's Scientists and Engineers

(1) Changes in Absolute Numbers: In All Industries and the Manufacturing Industry

The number of Japanese engineers has decreased since 2000 following the shrinkage of the macro labor market. In the manufacturing industry, which is the main receptacle for engineers, the labor market for engineers began to shrink earlier in the mid-1990s. We show these changes in Table 1.[3] From this table, using an index of 100 for 1980, we can see that after the number of scientists and engineers in all industries grew rapidly by a factor of 2.8 in 20 years, this number decreased more than 40 points in the five years since 2000. The manufacturing industry experienced a gradual decline—after the number of scientists and engineers grew rapidly by a factor of 2.6 in the 15 years from 1980, this number decreased 30 points in the ten years from 1995 to 2005.

The decline in the number of scientists and engineers, however, is relatively smaller in comparison to the decrease in total workers in all industries and as a result a steady up-

[3] Engineer is broadly defined here to include natural scientists engaged in R&D activities for the changes shown in Table 1.



Source: Population Census (Statistics Bureau of Ministry of Internal Affairs and Communications: MIC).

Figure 2. Change in the Ratio of Scientists and Engineers in the Manufacturing Industry: 1985-2005

wards trend can be seen in the ratio of scientists and engineers comprising all workers. For example, the proportion of scientists and engineers comprising the human resources in the manufacturing industry has continually increased from 1985 to present (Figure 2). There are also differences in this ratio within the manufacturing industry according to the type of business. For example, in two of Japan's large manufacturing sectors—the automotive industry and electronics manufacturing—the proportion of scientists and engineers engaged is two times higher in electronics manufacturing. It is thought that the proportion of scientists and engineers will further increase along with an expansion of digitalization in not only the automotive industry, but various manufacturing industries.

(2) The Low Proportion of Scientists and Engineers Comprising Workers in the Manufacturing Industry

Another quantitative feature of Japanese scientists and engineers was stated previously—the ratio of scientists and engineers comprising workers is low in comparison to other countries despite the above mentioned upward trend of recent years. However, as shown in Table 2, the industry-wide difference is not so great—5.1% in the U.S. and 4.2% in Japan. In particular, the difference is almost eliminated when the ratio is limited to the number of engineers—4.1% in the U.S and 4.0% in Japan. However, the results of a detailed comparison reveal the existence of big US-Japan difference. When we focus on the manufacturing industry, the ratio in Japan (5.4%) is almost half that of the U.S (10.1%).

Table 2. The Proportion of Scientists and Engineers in Japan and the U.S. (2000)

	Number of total workers	Engaged in R&D		
		Total	Natural scientists	Engineers
All industries				
Japan	2,676,227	4.20%	0.20%	4.00%
U.S.	*6,492,790*	*5.10%*	*1.00%*	*4.10%*
All manufacturing industries				
Japan	657,603	5.40%	0.30%	5.10%
U.S.	*1,805,927*	*10.10%*	*1.20%*	*8.90%*
Transportation equipment				
Japan	79,020	7.70%	0.20%	7.50%
U.S.	*353,264*	*15.10%*	*0.90%*	*14.10%*
Electronic				
Japan	240,560	11.60%	0.20%	11.30%
U.S.	*603,968*	*24.90%*	*1.70%*	*23.20%*

Sources: Japan = Population Census (Statistics Bureau of MIC). U.S. = CENSUS 2000 (U.S. Census Bureau).
Note: Industry and occupation classifications are based on Japanese criteria.

This large disparity in the manufacturing industry can even be confirmed at an industry sector level where similar products are produced. Table 2 is also taken up in Figure 2, and both indicate the ratio of scientists and engineers comprising workers in the automotive industry and electronics manufacturing—typical manufacturing industries. Japan's ratio is less than half that of the U.S. in these industries. The low ratio of scientists and engineers in Japanese manufacturing may be related to the breadth and depth of the skills of manual workers in manufacturing that complement the skills of engineers.

2. Qualitative Features of Japan's Scientists and Engineers

Now, let's look at the qualitative features of Japanese scientists and engineers.

(1) Education Level and Age Structure

Table 3 displays the educational training of Japanese engineers. Scientists were excluded from the table as it is difficult to accurately measure the proportion of scientists with a low-level education due to the low absolute number of scientists and the bias towards a high level academic background. From this table, we can understand that engineers consist of people with a high-level educational background. Even if we divide into information system engineers such as SE and other engineers including civil engineers and architects,

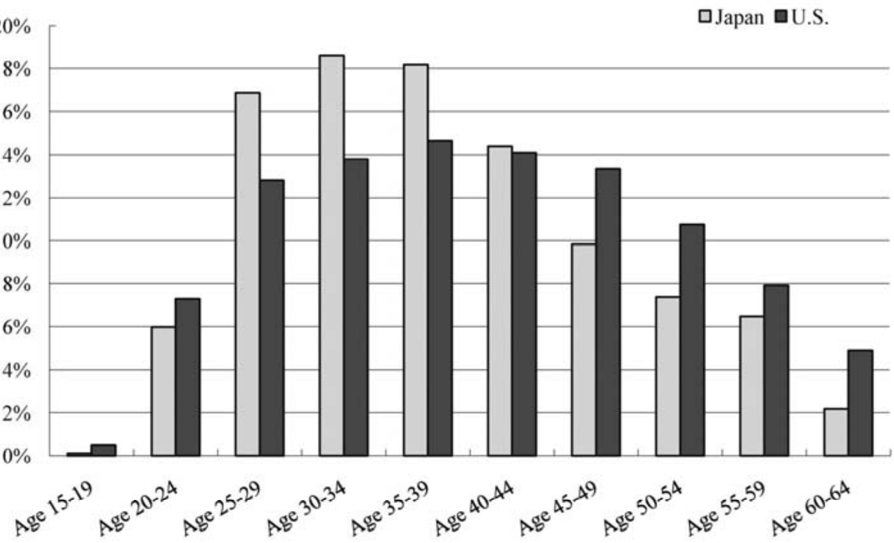
Table 3. Comparison of the Educational Attainment of Engineers in Japan and the U.S.: Employees under 65 Years of Age

Highest education completed	Japan		U.S.	
	Number	%	Number	%
All engineers				
No high school diploma	14,835	0.7%	20,132	0.3%
High school or equivalent	416,351	19.0%	1,330,572	***22.2%***
Junior college or equivalent	393,132	***17.9%***	624,947	10.4%
University or equivalent	1,042,578	47.5%	2,777,501	46.4%
Graduate school or equivalent	327,975	14.9%	1,229,068	***20.5%***
Information engineers				
No high school diploma	2,349	0.3%	17,801	0.5%
High school or equivalent	118,201	12.9%	774,538	***22.2%***
Junior college or equivalent	212,520	***23.2%***	321,090	9.2%
University or equivalent	486,669	***53.2%***	1,682,943	48.2%
Graduate school or equivalent	94,842	10.4%	693,049	***19.9%***
General engineers				
No high school diploma	12,485	1.0%	2,331	0.1%
High school or equivalent	298,151	23.3%	556,034	22.3%
Junior college or equivalent	180,612	14.1%	303,856	12.2%
University or equivalent	555,907	43.4%	1,094,558	43.9%
Graduate school or equivalent	233,134	18.2%	536,019	21.5%

Sources: Japan = *Employment Status Survey 2007* (Statistics Bureau of MIC). U.S. = *Current Population Survey,* 2008 Annual Social and Economic (ASEC) Supplement (U.S. Census Bureau and Bureau of Labor Statistics: BLS).
Note: Japanese data are excluding executives and workers currently undertaking education.

the results are similar. Over 60% of engineers have a university or higher level educational background. And there is also a weak presence of graduate school graduates in information systems (10%) and a stronger presence in general engineers (20%). However, the high academic background of Japanese engineers is by no means unique. This point is confirmed in a comparison with U.S. engineers who similarly consist of a high proportion of individuals with a high-level academic background—2/3 of U.S. engineers have a university or higher level educational background. The only discrepancy noticed between Japan and the U.S. concerns information system engineers—In Japan, a high proportion of information system engineers consist of junior (two year) college equivalent graduates and in the U.S. a high proportion consist of high school graduates and graduate school graduates.

Next, let's look at the age structure in Figure 3. For similar reasons as in Table 3, workers over the age of 65 are excluded. We can see that workers aged 39 and under



Sources: Japan = *Survey on Employment Structure (2007)*, employees only (admin. excluded)/workers currently undertaking education excluded. U.S.A. = *Current Population Survey*, 2008 Annual Social and Economic (ASEC) Supplement (2007 data).

Figure 3. The Age Structure of Engineers in Japan and the U.S. (2007): Employees under 65 Years of Age

comprise 60% of Japan's total engineers—an extremely young age structure. The youth of Japan's engineers is evident from a comparison with the age structure of U.S. engineers —Japan has a much greater proportion of engineers aged 25-39 while the proportion of engineers over 45 is much higher in the U.S.

(2) Patent Productivity

Now let's look at a quality indicator that is thought to have greater relationship to labor productivity. Previously, the relationship between labor productivity in the manufacturing industry and the ratio of scientists and engineers that comprise the total persons engaged in manufacturing was displayed in Figure 1. Unfortunately, as there is no internationally comparable labor productivity data that is limited to engineers in a similar way, here we use commonly used patent productivity data as a simple measure of engineer quality. There are several alternative measures of the patent productivity. Here, displayed in Table 4, we evaluate the quality of scientists and engineers with three indexes—the total number of patent applications, the total number of patents registered, and the actual number of patent applications. First, the total number of patent applications; this is the total number of patents filed by Japanese companies in various countries around the world. Similarly, the total number of patents registered is the total number of patents filed by Japanese companies in various

Table 4. Changes in the Patent Productivity of Engineers: A Comparison between Japan and the U.S. (per 1000 engineers)

	1995	2000	2005
Total number of patent applications			
Japan	300.4	360.0	482.0
U.S.	*95.7*	*131.1*	*198.9*
Total number of patents registered			
Japan	104.5	122.7	171.5
U.S.	*51.7*	*63.3*	*73.1*
Actual number of patent applications			
Japan	229.7	259.7	305.1
U.S.	*44.5*	*65.1*	*79.1*

Sources: Patents = WIPO Statistics Database, September 2010. Japan engineers = Population Census (Statistics Bureau). U.S. engineers = *Current Population Survey* ASEC supplement (U.S. Census Bureau and BLS). GDP = World Development Indicators (World Bank).

Note: In order to maintain data consistency, here architects and information engineers are excluded from the definition of "engineers." "Actual number of patent applications" means the patent family excluding duplicates for the purpose of applying in multiple countries.

countries around the world where review has been completed and registration of the patent has been granted. The final index, the actual number of patent applications, is the total number of patents when the same patent filed and registered in a number of countries is counted as the one patent as opposed to being counted as separate patents in each country. For this reason, the actual number of patents more accurately represents the production of patents of Japanese engineers while on the other hand the total number is the result of patent protection in multiple countries and can be said to reflect the global market value of patents. For these reasons, here we examine the quality of Japan's scientists and engineers with the three different indexes (production per 1,000 engineers). Table 4 displays the patent productivity of Japanese and U.S. engineers as expressed by those three indexes. Looking at the figures, we can see that the patent productivity of Japanese engineers has continued to rise steadily since the mid-1990s on all indexes. Furthermore, it can be confirmed on all three indexes that the patent productivity of Japanese engineers greatly exceeds that of their U.S. counterparts. It can also be confirmed that Japanese engineers retain their superiority even when this comparison is extended to other major countries and their patent productivity can therefore be said to be extremely high.

(3) Salary Levels of Engineers

While we have looked at the quality of Japanese engineers, their salary levels also

Table 5. A Wage Comparison of Japanese and U.S. Engineers (2007)

Standard: U.S. wage = 100

Conversion by:	Exchange rate		Purchasing power	
Wage unit:	Yearly	Hourly	Yearly	Hourly
Male				
Natural science researchers	80.5	86.7	72.6	78.3
General engineers (*Gijutsushi*)	62.7	62.8	56.6	56.7
Information engineers (System engineers)	57.1	54.0	51.6	48.7
Managerial staff	***91.0***	**105.4**	82.2	***95.1***
Female				
Natural science researchers	***93.6***	**104.1**	84.5	***94.0***
General engineers (*Gijutsushi*)	66.7	60.8	60.2	54.9
Information engineers (System engineers)	62.4	60.3	56.3	54.4
Managerial staff	**106.9**	**119.9**	***96.5***	**108.2**

Sources: Japan = *Basic Survey on Wage Structure* (Ministry of Health, Labour and Welfare). U.S. = *Current Population Survey*, ASEC Supplement (U.S. Census Bureau and BLS).

Note: The exchange rate is based on the standard foreign exchange rate and a fixed exchange rate. The purchasing power rate is based on IMF PPP Comparison. Parenthetical words next to job names are used in Japanese data.

provide an economic valuation of quality. Here, let's see if their salary levels are consistent with the discussion of quality utilizing the three indexes that we looked at by comparing the salaries of Japanese and U.S. engineers.

A comparison of the salaries of Japanese and U.S. engineers with an adjusted currency unit is displayed here in Table 5. Calculation based on the USD/yen exchange rate as well as a calculation based on a purchasing power parity were both considered as methods of creating an adjusted unit of currency and a comparison was undertaken using both methods. With both methods, the results show that the salary level of Japanese scientists and engineers is significantly lower than their U.S. counterparts on a yearly and hourly basis. SE salary—a typical position for information industry engineers—was particularly low in Japan at 60% or less compared to the U.S. average SE salary. The only exception is seen in female natural scientists where there is little difference in salary between Japan and the U.S, particularly at an hourly rate. Despite the relatively low salary of these various Japanese scientists and engineers, there is little difference in salary among management positions in the two countries. That is to say, the salaries of Japanese scientists and engineers are relatively low in comparison to other domestic jobs, and engineers only receive wages on par with their U.S. counterparts after they are promoted to a management position in Japan.

Table 6. Transfer Ratios by Occupation (2007, male regular employees)

	Engineers			Clerical staffs	Sales and marketing staff	Manual workers	All occupations
	Total	*General engineers*	*Information engineers*				
Total	7.6%	*5.9%*	*10.2%*	5.4%	7.7%	7.5%	7.2%
Age 25-29	15.0%	*14.0%*	*16.0%*	12.7%	12.3%	10.6%	12.0%
Age 30-34	4.6%	*3.4%*	*6.4%*	4.7%	6.8%	6.6%	6.4%
Age 35-39	5.0%	*3.7%*	*6.5%*	3.2%	4.7%	4.6%	4.6%
Age 40-44	1.7%	*1.8%*	*1.7%*	2.5%	4.2%	3.8%	3.6%
Age 45-49	2.0%	*1.6%*	*2.6%*	1.8%	3.3%	3.1%	2.8%
Age 50-54	2.7%	*1.1%*	*8.1%*	1.7%	3.8%	2.8%	2.9%
Age 55-59	2.6%	*2.9%*	*1.0%*	2.6%	2.7%	3.0%	3.0%

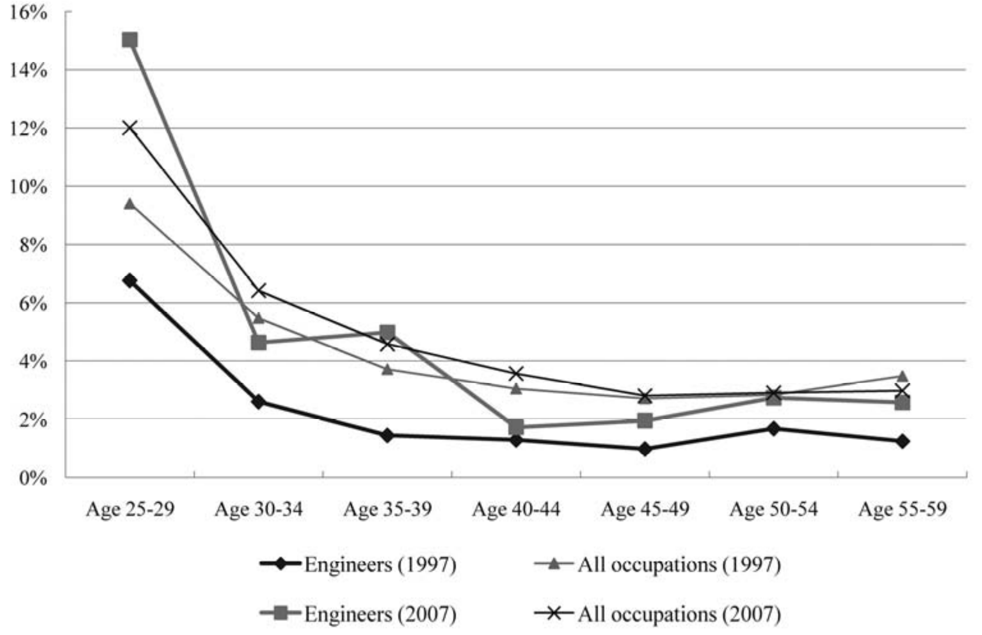
Source: Employment Status Survey (Statistics Bureau of MIC, Recounted).
Note: In this paper, hiring rates are the rate of employees with tenure of less than a year.

II. Changes in Mobility of Japanese Scientists and Engineers

1. The Transfer Ratio of Japanese Scientists and Engineers and Changes in This Ratio

(1) A Comparison of the Transfer Ratios by Occupation

Now, what kinds of changes are occurring in the workplaces of these Japanese scientists and engineers with the above quantitative and qualitative features and what kinds of changes are occurring in the external labor markets surrounding them? First, the number of worker turn-over during a fixed period of time is regarded as an indicator of external labor market development, so let's take a look at yearly ratios. Japan is said to be a country where the external labor market is undeveloped, but on the other hand, if the mechanisms for intra-company transfers is considered a market mechanism then Japan can be said to have a highly developed internal labor market. However, there are also countries such as the U.S. where an external labor market has developed for highly skilled professionals such as engineers. Can development in the external labor market for engineers been seen amid the developing trend towards non-regular employment in the Japanese labor market in recent years? The estimated ratio of job changers and new entrants into their current workplace within the previous year by occupation is displayed in Table 6 in order to answer this question. Looking at the average ratio of all engineers, there are no significant discrepancies in comparison to the ratios for other occupations. In fact, engineers are placed in the middle of



Source: *Employment Status Survey* (Statistics Bureau of MIC, Recounted).

Figure 4. Engineer Hiring Rate by Age Group (Male regular employee): 1997 vs. 2007

the distribution. If clerical staffs are excluded, the yearly ratio for male Japanese employees (including engineers) is around 7%. However, if we further divide engineers into information system engineers and other engineers, the ratio of information system engineers is double that of the other engineers and we can see a high level of labor market externalization there. Furthermore, the table suggests that the ratio is greatly influenced by age across all occupations. A pattern can be seen in that engineers in their 30s are comparatively mobile—this mobility decreases as they reach their 40s and they then become mobile once again as they approach retirement age. Are changes occurring to this age transfer pattern?

(2) Has the Mobility of Scientists and Engineers Increased in Recent Years? A Comparison between 1997 and 2007

In order to identify the externalization of the engineer labor market we compared the average ratio of job changers and new entrants among engineers as well as the ratio over all occupations classified by age in 1997 and 2007 and displayed them in Figure 4. From this, we can see that there is a significant difference between the changes in the engineer ratio and changes in the overall ratio. If we look at the overall ratio across all occupations we can see a slight increase in the ratio of young persons from 1997 to 2007, however a time oriented change cannot be observed in the middle age group. On the other hand, it is clear that the external labor market for engineers has developed—the ratio for engineers has significantly

Table 7. Ratio of Employees Transferred within the Previous Five Years (Male regular employees aged 64 and under)

	1997	2002	2007
Engineers	7.6%	9.4%	11.5%
General engineers	—	*7.8%*	*9.4%*
Information engineers	—	*12.1%*	*14.7%*
Clerical staffs	7.8%	10.4%	10.8%
Sales and marketing staffs	14.3%	16.9%	17.0%
Manual workers	15.5%	15.1%	15.5%
All occupations	13.4%	14.6%	14.7%

Source: *Employment Status Survey* (Statistics Bureau of MIC, Recounted).
Note: "Transferred employees" in this table refers to employees who have been transferred within the previous five years at the time of the survey. There is no breakdown of engineers for the 1997 data due to limitations.

increased across all age groups from 1997 to 2007. In fact, the ratio has doubled in all age groups except the 40-44 age group. These statistics, however, reflects the growing share of information system engineers where there is a highly developed external labor market.

2. Changes in the Ratio of Job Changers and New Entrants among Japanese Scientists and Engineers within the Previous Five Years and Their Length of Their Service

(1) The Ratio of Job Changers and New Entrants within the Previous Five Years by Occupation and Changes in This Ratio.

The ratios discussed in the previous section are an indicator of the movement of workers within a given year, this time one year, and are a valuable indicator to provide insight into the circumstances of that particular year. However, labor movement is significantly affected by economic cycles and so it is difficult to compare this data to data taken in another year with a similar cycle due to the limitations of available data that year. In that regard, comparison by compiling multiple sets of stock data obtained at particular times dilutes the effect of a particular year and the cumulative trends of a wide observation period can be compared. So in Table 7, we display the aggregated ratio[4] of workers transferred within the previous five years by occupation. The engineer job changers and new entrants ratio varies slightly by sex and employment status, however due to the limited space we will

[4] An application was made to the Statistics Bureau for use of their questionnaire information under the Statistics Act and our result is a recount of that data.

Table 8. Engineer Average Years of Tenure by Age Group

	All employees (Male and female)			Regular employees (Male)		
	1997	2007	Change	1997	2007	Change
Age 25-29	4.82	3.27	-1.55	4.88	3.30	-1.58
Age 30-34	8.51	7.14	-1.37	8.80	7.48	-1.32
Age 35-39	12.04	11.14	-0.90	12.47	11.83	-0.64
Age 40-44	16.51	16.02	-0.50	17.66	16.98	-0.69
Age 45-49	21.19	19.61	-1.58	22.40	20.93	-1.47
Age 50-54	25.07	23.44	-1.63	26.70	25.00	-1.71

Source: *Employment Status Survey* (Statistics Bureau of MIC, Recounted).

focus on full-time male employees, the largest demographic. The first thing that can be confirmed is a high growth in the ratio of engineers job changers and new entrants within the previous five years, even amidst the overall increase in all occupations. Another interesting point is that in comparison to other occupations, the ratio of information engineers such as system engineers falls under the "high" category, while the job changers and new entrants ratio of engineers in traditional fields other than IT (hereafter referred to as "general engineers") is extremely low. Essentially, what can be confirmed in the comparison of the job changers and new entrants ratios between jobs and their change in the previous section, even in the stock data, is the externalization of the engineer labor market and differences in the progress of labor market externalization between the two different groups of engineers.

(2) Changes in Length of Service by Occupation (1997 vs. 2007)

Let's continue the analysis of stock data and have a look at how long on average scientists and engineers work continuously for the same organization (company). The flow and stock indexes used so far have focused on worker transfer. The average length of service looks at the segment of workers who do not transfer. The reason for looking at this index is to find if there is a change in the ratio of workers who don't transfer that couldn't be reflected in the previous two indexes. For example, flow indicators will appear the same regardless of whether similar workers change their jobs every year or whether that ratio consists of different workers each year. However in stock indexes, the figure will grow higher year-by-year in the case of a ratio consisting of different workers. The reason for looking at the average length of service of all workers is that it reflects changes in long-term flow better than accumulated stock data limited to five years of flow. So, let's look at the data in 1997 and 2007 concerning the length of time engineers have been working at their present companies and estimate the average by age group. There are two reasons for estimating the length of service by age group, firstly because the maximum of length of service is restricted by age and secondly, that changes in the age structure of engineers have occurred within these ten years of our observation. When age structure changes, the effect of labor market externalization cannot be distinguished by looking at the overall average. The estimated results obtained in this manner are displayed in Table 8: average length of service. The 55-year-old and over age group was excluded because due to the extension of the retirement age in many Japanese companies recently, their data would boost the average length of service and the effects of externalization would not be properly ascertainable.

Looking at this, the average length of service of engineers has decreased within this period in all age groups. From this result, we can confirm that the externalization of the engineer labor market is not only progressing in the younger age groups and over-50s age group but is a general change encompassing all age segments.

III. Changes in the Workplace Environment Surrounding Scientists and Engineers

1. Changes in the Employment System of Engineers

So, what factors have caused the externalization of scientists and engineers as shown above? Here we examine this with a focus on their workplaces with particular attention given to company employment systems, personnel evaluation systems and salary systems and the effects that they have.

First, let's look at current employment systems and their recent changes. For reference, the results of a survey carried out in 2008 on companies affiliated under the Japanese Electrical Electronic and Information Union are listed below. Within the Japanese manufacturing industry, the electronic industry, along with automobile manufacturing, is the most important industry in terms of the volume of employment and creation of value added and has the highest ratio of engineers in the manufacturing industry. Therefore, the electronic industry is thought to be the most appropriate industry to gain insight to the current conditions of engineers and changes in conditions.

The features of the employment system of Japanese companies are said to be that internal workers are valued and stable employment is guaranteed to them. Does this kind of employment system still exist today in the rapidly evolving electronic industry or are changes already beginning? Table 9 is a summary of the answers regarding changes in the employment systems of 63 of the major companies in the industry.

First, 80% of companies responded that there have been increases in the mid-career recruitment of engineers as well as all other employees. Similarly, 60% of companies responded that there has been a strong trend towards the wider use of external talent both for engineers as well as all other employees. The externalization of employment systems has been steadily progressing as far as we can see from these figures. These results are also consistent with the other various statistics we have looked at until now that support the

Table 9. Changes in Human Resource Management in the Previous Five Years: For Engineers and All Employees (2008)

	Expanded	Slightly expanded	Almost no change	Slightly reduced	Reduced	No response
Mid-career recruitment						
Engineers	*31.7*	**50.8**	15.9	0.0	0.0	1.6
All employees	*19.0*	**60.3**	17.5	0.0	0.0	3.2
Use of external resources						
Engineers	9.5	**47.6**	*41.3*	0.0	0.0	1.6
All employees	12.7	**50.8**	*34.9*	0.0	0.0	1.6
Long-term stable employment						
Engineers	3.2	3.2	**76.2**	*12.7*	3.2	1.6
All employees	3.2	3.2	**73.0**	*15.9*	3.2	1.6

Source: Japanese Electrical Electronic and Information Union (2008), *Survey Report*, no.374.

externalization of scientists and engineers. So, is the movement towards externalization accompanied by changes in the employment systems for full-time workers, in particular engineers, leading to decreased employment stability? As far as we can see from looking at Table 9, such changes are still not of significance. The majority of companies still adopt a basic policy of stable long-term employment and only a small number of companies (16%) have recognized abatement in the stable long-term employment of engineers. However, this recognition of the weakening of stable long-term employment in a 16% ratio of companies that can't be overlooked together with the movement towards externalization already identified is evidence that a major change is taking place discretely.

2. Changes to Scientist and Engineer Personnel Systems

(1) Changes to the Salary System of Scientists and Engineers in the Past Five Years

So, have changes to personnel evaluation systems also been occurring to ensure consistency with the externalization of employment systems as seen above? First, let's look at changes in salary systems. To what extent have performance-based salary systems passed through to engineers?

Table 10 displays the various changes to the salary systems of engineers that have occurred in the past five years (survey taken in 2008) based on the survey data in the previous table.

First, let's look at the changes in base salary regarding regular (annual) pay raises, which have been the major system up until now, and performance-based pay. We can see

Table 10. Changes in the Salary System of Engineers in the Past Five Years

	Expanded	Slightly expanded	**Almost no change**	Slightly reduced	Reduced	No response
(A) About base wage						
Regular (annual) pay raises	3.2%	4.8%	**44.4%**	*20.6%*	*15.9%*	11.1%
Salary based on job capability evaluation	4.8%	*19.0%*	**58.7%**	6.3%	3.2%	7.9%
Salary based on personal performances evaluation	*19.0%*	*25.4%*	**44.4%**	4.8%	1.6%	4.8%
Based on team or department performances evaluation	3.2%	3.2%	**66.7%**	1.6%	0.0%	25.4%
Salary based on job and position	*15.9%*	*15.9%*	**52.4%**	4.8%	0.0%	11.1%
Linkage of internal salary to external labor market conditions	1.6%	6.3%	**65.1%**	7.9%	0.0%	19.0%
(B) About bonuses						
Linkage between bonus and personal performances	*12.7%*	*34.9%*	**46.0%**	1.6%	0.0%	4.8%
Linkage between bonus and team or department performances	7.9%	3.2%	**65.1%**	1.6%	1.6%	20.6%
Linkage between bonus and company performances	*12.7%*	*17.5%*	**58.7%**	0.0%	0.0%	11.1%

Source: Japanese Electrical Electronic and Information Union (2008), *Survey Report*, no.374.

that there is a trend of an expansion or slight expansion in the proportion of salaries "based on job capability evaluation" while 36% of companies have reduced regular (annual) pay raises. This represents a move in different directions of the two pay elements that have been the backbone of the Japanese salary system until now. The regular (annual) pay raise system promotes long-term service and is incompatible with externalization. Therefore, the large-scale reduction in regular (annual) pay raises we have seen is consistent with the flow of labor market externalization.

So, can new movements within the salary system to promote further externalization be seen? Such movements concern performance-based salaries—45% of companies have strengthened their “individual performance/achievement” performance-based salary system, which promotes externalization. However, we can also confirm that company salary levels are not yet directly linked with market wage levels and the labor market conditions.

The situation regarding bonuses is similar to the situation regarding base salary. From the table we can see a growing linkage with individual achievement—46% of companies have strengthened the linkage between their bonuses and individual achievement. Furthermore, 30% of all companies have also strengthened linkages to company achievement and 11% have strengthened linkages to team/department achievement. So, we can also see a steady increase in performance-based bonuses consistent with the externalization of employment systems from these figures.

(2) Annual Salary of Scientists/Engineers and Determining Factors

So, can the transition to performance-based salary systems we looked at above also be confirmed in the determination of the salary levels of engineers? We combined survey information obtained from approximately 3,000 non-managerial engineers working in large- and medium-size companies in the electrical/electronic industry with the information on the employment and personnel system, etc, of the companies that they work for and undertook a multiple regression analysis to determine what kind of correlation exists between engineers annual salary and not only individual factors, but organizational factors such as each company’s human resource management system. Let’s look at the effects of changes in the salary system using these results.

From Table 11, we can see that that the method of determining the salary of engineers working in the electronic industry corresponds extremely well to the recent changes in employment and personnel systems in the industry discussed in the previous section. The dependent variable in the regression analysis was each engineer’s annual salary. Essentially, the monthly salary x 12 + yearly bonus was the target of explanation in this regression analysis. The explanatory variables were the factors cited in the left column of the table. We tested three combinations of explanatory variables to express each engineer’s willingness to work—The feeling of “fulfilling work” in model 1, “company loyalty” in model 2 and a combination of both in model 3. We confirmed that regular (annual) pay raises are still implemented in the majority of companies and under the system of an annual increase in salary with regular pay raises, a strong positive partial correlation between age and annual salary can be assumed. In fact, the estimated age variable coefficient was positive and confirmed to be statistically significant under all models (1-3) in the table. In addition, the engineer’s capability variable is suggested to have a positive effect on yearly salary in job capability based salary systems in which progressive expansion has been confirmed in recent years, and a statistically significant positive coefficient value is estimated in practice. So, the spread in recent years of the performance-based salary systems that are the focus of our

Table 11. Annual Salary Analysis

Dependent variable is a logarithm of annual earning			
	Model 1	Model 2	Model 3
Explanatory variable	Coefficient	Coefficient	Coefficient
Constant term	4.835 **	4.801 **	4.817 **
Female dummy	-0.127 **	-0.127 **	-0.125 **
Age	0.033 **	0.033 **	0.033 **
High academic background	0.047 **	0.047 **	0.047 **
Ability as an engineer	0.017 **	0.016 **	0.016 **
Motivation to work	-0.011	N.A.	-0.015 +
Corporate loyalty	N.A.	0.016 *	0.018 **
Job satisfaction	0.007	0.001	0.006
Overtime work	0.002 **	0.002 **	0.002 **
Job discretion	0.000	0.000	0.000
Importance of work	0.047 **	0.044 **	0.046 **
Positive workplace relationships	-0.002	-0.005	-0.003
Comfortably challenging workplace culture	0.006 *	0.005	0.006 +
Change in R&D expense ratio to sales in the past 5 years	0.028 **	0.030 **	0.030 **
Personal performance indicator	0.021 **	0.019 **	0.020 **
Product category engaged in (standard: capacitors, batteries, etc.)			
Semiconductors	0.010	0.012	0.011
Electronic components other than semiconductors	0.038 +	0.036 +	0.036 +
Motors, elevators, robots, etc	-0.023	-0.020	-0.021
Transformers, control instrumentation, switchboards, etc	-0.041 +	-0.040 +	-0.041 +
Plant related	0.007	0.011	0.010
Commercial/business equipment	-0.045 *	-0.042 *	-0.043 *
Consumer electronics and related electrical equipment	0.027 +	0.028 +	0.028 +
Individual solutions	0.030	0.033 +	0.032
Software development, network construction	0.034 *	0.039 *	0.037 *
Other	0.016	0.018	0.017
Corporate performance trend	0.006 *	0.006 *	0.006 *
R^2	0.519	0.520	0.520
Adj. R^2	0.515	0.516	0.516
D.W.	1.767	1.770	1.772
F value	138.7 **	138.9 **	133.5 **
Sample size	3108	3106	3106

Note: **= 1% significance, * = 5% significance, + = 10% significance.

attention means that individual performance indicators have a strong positive effect on salary and the results from the table confirmed this with the expected significant positive coefficient. Furthermore the spread of job/position based salary could be confirmed with the "Importance of work" variable having a strong positive effect on salary. In addition, the fact that the trend of engineers having responsibility of their respective product (project) area and corporate performance has a strong positive effect on yearly salary levels also corres ponds to the direction of change which we previously looked at in the bonus system.

From the above results we can see the changes in the personnel and salary systems we looked at previously and that the determination of engineer salary levels is regulated through the actual operation of these systems at present.

IV. The Relationship between Changes in Employment and Personnel Systems and Externalization of the Scientist and Engineer Labor Market

From the analysis so far, various indicators have confirmed a gradual increase in the turn-over of scientists and engineers as well as a shift in the direction of labor market externalization. We have also confirmed that Japanese companies have experienced parallel changes in their employment and personnel systems consistent with this movement towards labor market externalization. Now, let's see if there is a cause and effect relationship between these two consistent trends. Do system changes create externalization or does externalization drive changes in the system? We haven't come across any previous studies to give us a clear answer as to the cause and effect relationship between the two. Here, let's say the employment and personnel system changes discussed in this paper encourage externalization and are necessary for the employment and treatment of more mobile scientists and engineers in line with business objectives. While we can't delve into a further study of this cause and effect relationship in this paper, we can however introduce data that could be a reference for future discussion and discuss the meaning of this data. This data concerns the feelings of scientists and engineers. Essentially, that a change of heart is required in order for employees to take the action of leaving their company—a so-called "willingness to change jobs." This willingness to change jobs is coupled with a change in the worker's previous perception towards their company and work. So, let us show what kinds of changes have occurred in the hearts of scientists and engineers together with the changes in the systems and labor market shown above.

1. Changes in Feelings towards Their Jobs and Their Companies

When scientists and engineers feel disillusioned towards the company that they (until then) belonged to for whatever reason, they will follow their inner feelings and move between organizations, seeking a workplace with a better job. So, how have the feelings of Japanese scientists and engineers changed towards their job and company? Here we examine data on union workers collected by the Japanese Electrical Electronic and Information Union regarding job fulfillment and attitudes towards their companies.

Something that needs to be recognized is that these feelings tend to vary by age, sex and length of service, and recent changes in the composition of age, sex and length of service could have a major influence on this data regarding changes in attitudes. So here in

Table 12. Changes in Feelings towards Jobs and Companies by Occupation (Adjusted)

Occupation	Motivation to work			Corporate loyalty		
	1994	2005	Change	1994	2005	Change
General engineers	0.45	0.15	-0.30	0.03	-0.28	-0.31
Information engineers	0.25	-0.09	-0.35	-0.01	-0.32	-0.31
Manual workers <Standard>	0.00	0.00	0.00	0.00	0.00	0.00
Clerical staff I (university graduate or above)	0.21	0.26	0.05	0.32	0.08	-0.24
Clerical staff II (junior college or below)	0.03	-0.10	-0.14	0.17	0.16	-0.01
Sales and marketing staffs	0.31	0.28	-0.02	0.14	0.25	0.11

Sources: Fujimoto and Nakata (2007), table 6, table A2. Original data: Japanese Electrical Electronic and Information Union Member Surveys 1994/2005.
Note: Manual workers were standardized to 0.

Table 12, we look at employee feelings towards their job and company after adjusting for the effect that the above composition changes have on data. These numerical values regarding the feelings of workers in each occupation represent the relative difference from the feelings of manual workers engaged in manufacturing.

First, looking at the changes in the relative levels, the levels of work motivation among engineers (both general and information system engineers) were extremely high in comparison with other occupations in 1994; however the high motivation decreased significantly in the following ten years and as a result their work motivation was about level with other occupations in 2005. On the other hand, company loyalty among both kinds of engineers has been the lowest amongst all occupations, on par with manual workers since the first survey in 1994, and it declined even further over the following years until 2005.

In other words, we can see the rapid decay of employee attachment to their jobs and companies in recent years as a trend amongst all scientists and engineers. The timeframe in which these surveys were carried out, around 2000, was a period when large-scale restructuring (cutbacks in personnel) was taking place in many electronic companies and the previous climate of long-term stable employment changed significantly. Did the retreat from a regular (annual) pay raise system which evaluates long-term familiarization and the change to a system evaluating shorter-term results along with the kinds of changes to employment systems we looked at in the previous section cool the engineer's feelings towards their company and jobs while increasing their desire to change those jobs? Let's examine these changes further.

Table 13. The Ratio of Engineers Wishing to Change Jobs

	1997	2007	Change
Age 20-24	16.23%	17.70%	1.47%
Age 25-29	16.88%	15.91%	-0.97%
Age 30-34	13.39%	15.05%	1.66%
Age 35-39	7.67%	12.25%	**4.58%**
Age 40-44	6.49%	9.39%	**2.89%**
Age 45-49	3.74%	6.11%	**2.37%**
Age 50-54	3.62%	5.23%	1.61%
Age 55-59	3.61%	5.21%	1.60%

Source: *Employment Status Survey* (Statistics Bureau of MIC, Recounted).

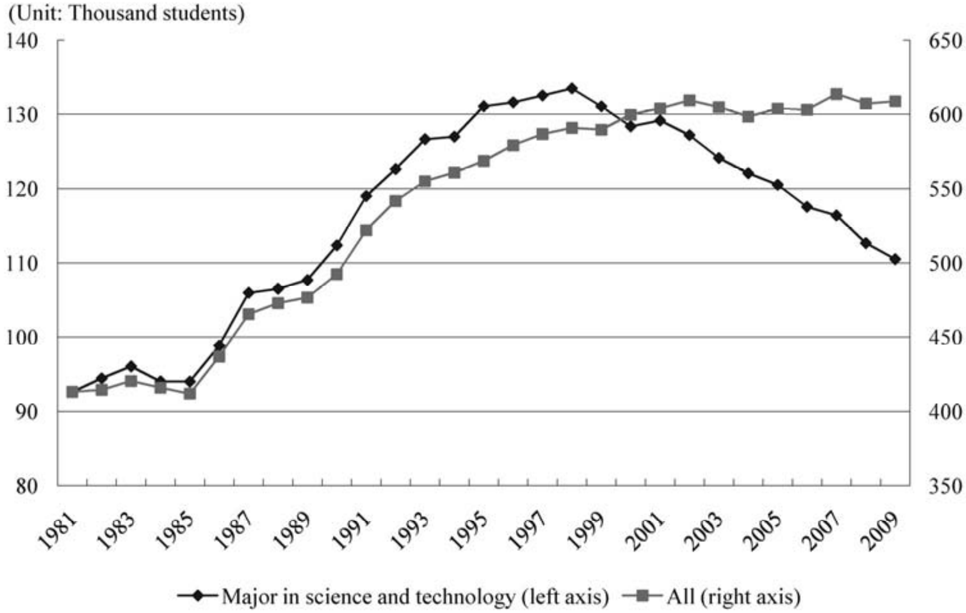
2. Growing Desire to Change Job

Table 13 displays the ratio of engineers wishing to change jobs grouped by age in 1997 and 2007—around the same timeframe as the above Table 12.

The right hand column of the table is the change of % share of those wishing to change jobs in the corresponding age group over 10 years. The increase in the ratio of engineers wishing to change jobs from 1997 to 2007 is obvious—the ratio increased over all age groups with the exception of the 25-29 year-old age group. Interestingly, the highest increase in ratio was seen in the 35-49 year-old middle-aged group where the transfer rate has been the lowest. The actual transfer rates looked at earlier indicate low mobility and high job stability in this age segment; however, the trend towards higher mobility can be confirmed by the feelings of these workers. We can say that as a result of this, greater turn-over in this age segment can be predicted in the near future.

V. The Future of Japanese Engineers

In this paper, we examined the present situation of the labor market for Japanese scientists and engineers and its recent changes. We learned that they are young, highly educated and very productive, which explains why the Japanese manufacturing industry has achieved high labor productivity with a relatively small share of such workers. Despite their high contribution to value-creation, they are treated relatively poorly in comparison to their international counterparts. This is made possible by insulating them from the external labor market forces. But now new reality of the labor market is emerging. While the Japanese labor market for scientists and engineers shrinks, there is a steady increase in



Source: National Institute of Science and Technology Policy (2010).

Figure 5. Changes in the Number of Students Entering University per Year

externalization. So, what future lies in the wake of these trends? The future decrease in domestic supply of scientists and engineers is the key to correctly forecasting the future shape of the Japanese scientist and engineer market. As made clear in Figure 5, the number of science and technology students in Japanese universities has continued to decease steadily since 1998. The majority of students studying science and technology at university now will bear the responsibility for Japan's manufacturing as graduate scientists and engineers in a few years and a reduction in the supply of new human resources is inevitable in the near future. The problem isn't just limited to numbers; the reduction in the amount of new workers will naturally result in a reduction of highly capable engineers and this will become a factor in the further decline in the research and development capabilities of Japanese companies.

The current trend towards the externalization of the labor market may enhance the overall macro efficiency for the utilization of scientists and engineers. But it is doubtful if market externalization will solve the problem above. So, are there any measures that can be taken in regard to the decline in both the quantity and quality of Japan's science and technology personnel? The solution may well be the proactive training of female engineers and calling upon more international university students studying to be engineers. International science and technology students at Japanese universities now will have a lead role when

Japanese companies expand their research and development activities overseas. In addition, female engineers with perspectives differing from their male counterparts are a great source of new ideas. These people may be able to play the role of the leading the transformation of Japanese companies into truly diverse global organizations, as well as engaging in research and development as talented scientists and engineers in their own right.

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