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Sustainability of Engineers' High Performance

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In this paper, we first ask how the performance of Japanese engineers is determined. To answer this, we construct a determination model based on the hearing of 9 leading manufacturing companies in Japan. We then ask how much this model can explain the variation of performance as well as the rewards of the performance. To answer this question, we fitted this model for the unique dataset mentioned above. The summary and discussion of the multivariate analysis follows. In the following section we discuss the changing workplace environments as well as the macro environment, including labor market and the product market. We argue that those changes are in general counter-productive for sustaining the high performance of the Japanese engineers. We then conclude the paper by discussing the policy implications as well as these for the management.

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Introduction : High performance of Japanese engineers

The last two decades is not an impressive period of Japanese manufacturing industries despite the global recognition of their highly regarded manufacturing technology, including their engineers' high performance. Actually there is evidence to indicate some impressive improvement their performance, both relative to counterparts of other countries and over time.

Table 1 shows the 15 year change of engineers' patent productivity of three leading industrial nations. Despite the global total decline of both US and Germany, Japan increased its patent productivity almost 50%. As a result, Japan now excels with a large margin compared to those two countries. This performance is a factor behind the continuous improvement of her labor productivity even during the prolonged recession in the 1990s and 2000s as we can see in Figure 1. Japan's manufacturing productivity has improved more than 40% in real term in 10 years between 1995 and 2005 and is now comparable to that of US with other industrial countries behind with large margin. Particularly I want to emphasize that her high manufacturing labor productivity is realized with the least share of R&D occupations, including engineers and SEs, among those 5 countries.

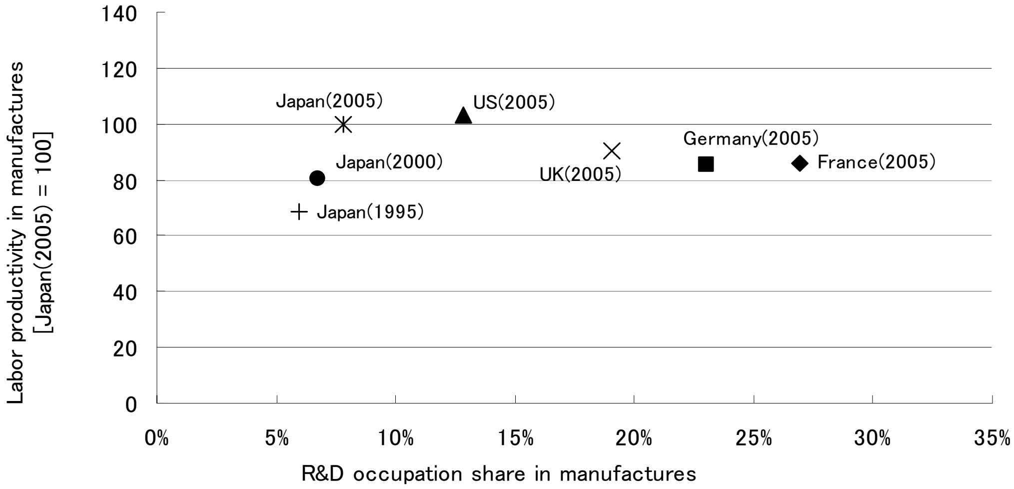
Table 1. Patent grants per 1,000 researchers (FTE)

	Year	Japanese	German	American
EPO (EU)	1991	**9.9**	27.0	6.1
	2005	**13.5**	45.0	9.4
JPO (Japan)	1991	**62.0**	4.9	2.6
	2005	**157.6**	6.5	3.7
USPTO (USA)	1991	**42.8**	31.8	52.1
	2005	**43.0**	32.5	53.8
Global Total	1991	**179.0**	298.0	126.6
	2005	**258.9**	169.3	89.7

(Source) Patent grants: WIPO Industrial Property Statistics
Number of researchers: OECD Main Science and Technology Indicators

Figure 1. R&D occupations share and labor productivity in manufactures

(Source) ILO LABORSTA/ OECD National accounts/ National accounts (Japanese CAO)



These facts motivated this paper. We ask the following questions, whose answers are produced based on the unique dataset on the Japanese engineers and their managers with a matching company data where they work. We first ask how the performance of Japanese engineers is determined. To answer this, we construct a determination model based on the hearing of 9 leading manufacturing companies in Japan. We then ask how much this model can explain the variation of performance as well as the rewards of the performance. To answer this question, we fitted this model for the unique dataset mentioned above. The summary and discussion of the multivariate analysis follows. In the following section we discuss the changing workplace environments as well as the macro environment, including labor market and the product market. We argue that those changes are in general counter-productive for sustaining the high performance of the Japanese engineers. We then conclude the paper by discussing the policy implications as well as these for the management.

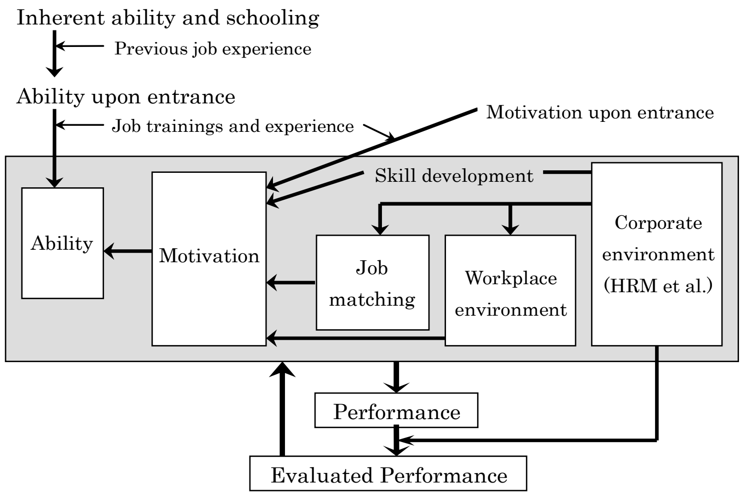
1. What are the determinants of engineers' performance?

The last two decades are said the decades of open innovation. As the United States is the pioneer and the front runner of open innovation, industrial leaders in other countries have made utmost efforts to import various aspects of what is said constitutes the open innovation. Japan is no exception. Executives of technology oriented companies as well as academics and policy makers alike followed the suite.

Interestingly what have been found lately about the way the Japanese engineers work is not what those efforts to implant the Silicon Valley type open innovation are expected to bring about. By any measure the Japanese engineers are not working like their counter-parts in the Silicon Valley. They spend most of their time in the company they belong to. They consult in most cases with their colleagues in the same company when they face technical problems. They participate less often professional meetings. But yet they perform at the level par to the top performers of open innovation.

So we visited 9 leading Japanese manufacturers and directed our questions to the managers and executives in charge of engineers' HRM and MOT. Five factors have emerged as critical to high performance of engineers based on the hearings. Two are engineers' capability and motivation. Third one is about job. Forth one is about workplace. And the last one is about company. These five factors are implied to relate each other as you see in the figure 2.

Figure 2



We then tested the validity of this model using the data set constructed by the survey result from 4300 engineers and their managers. This data set includes all the information about the first 4 factors for both engineers and their managers. We further enrich it by merging this data set with another, which consists of all the relevant information about the 76 Japanese manufacturers, whose engineers and their managers are surveyed for the first dataset.

2. Results of the analysis.

The analytical result is shown in Table 2. It is impressive. All the five factors are relevant in the determination of the performance of the Japanese engineers. In other words, the model has shown its appropriateness to represent the interrelationship between the performance level of engineers and the factors we expected to dictate it. As for the ability not only the self-evaluated competency as an engineer but also a more general capability, which is represented by their educational level, have proven to have a positive effect on the performance. As for the motivation, we tried out two alternative motivation variables, work motivation and company loyalty. The result rejected the company loyalty, but the work motivation has shown a strong positive effect on the performance. For job factor we experimented with 4 variables. They are 1) job matching, 2) job discretion, 3) importance of job, 4) over-time working hour. All of them have been proven relevant with a positive effect on the performance. As for the workplace environment, two variables, good human relationship with colleagues and open/pro-active atmosphere at workplace have had a positive impact on the performance. Lastly, among company characteristics, only the change of the research and development ratio to sales has shown a positive correlation to the performance level of engineers. An institution of Seikasyugi (Performance-based) HRM has had no relationship with the performance level, which is the opposite to what the management expect and hope.

Table 2: What determines the engineers' performance?

Factor	Variable	Effect
Individual characteristics	Female	
	Age	+
Ability	**Education**	+
	Self-evaluated competency	+
Motivation	Company loyality	
	Work motivation	+
Job characteristic	**Job matching**	+
	Over-time working hours	+
	Job discretion	+
	Important job	+
Workplace enviroment	**Good human relationship**	+
	Open/Pro-active atomosphere	+
Company characteristic	**R&D sale ratio change**	(+)
	Performance-based HRM	

Note: "+" means positive effect and "(+)" means positive effect with using only 'work motivation' as motivation factor. We use 10% significance level.

Summing up all the results above, we can safely say that the model we proposed is well supported by the data, and thus we conclude that the individual performance of the Japanese engineers are strongly affected by job, motivation, ability, workplace factors. And the company factor like the type of HRM seems rather marginal or indirect as we could not detect a direct strong correlation between the performance and relative to those four factors.

3. Changing environment of job, motivation, ability and workplace

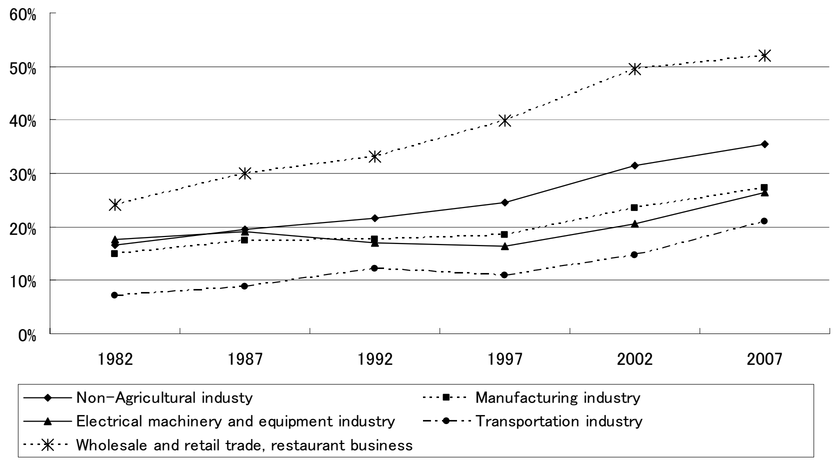
All the factors positively worked for the high performance of Japanese engineers have changed in the last 10 to 15 years.

A) Shrinking regular employment and increasing non-regular employment

:In the last two decades Japan has experienced a dramatic change of its employment structure. It is a shift from regular to non-regular employment. Japanese firms regardless industry they belong and big and small alike shredded off regular workers and substituted them with non-regular workers. Non regular employment constituted only 15% in 1982 for the Japanese employee, but 20 years later it more than multiplied and is increasing its shifting speed since then.

Figure 3. Shifts in percentages of non-regular employment

Sources: 'Employment status survey' (Ministry of Internal Affairs and Communications)



Engineers are not exception of this trend. For the population of our surveyed firms, 43% of them reduced their regular employment more than 5% in the last 5 years. And the number is 31% for engineers.

B) Consequential increase of regular engineers' working hours

:As a consequence of the shrunken regular engineers size, they now work much longer. Even in 1997 the engineers worked long compared to other occupations. But in 2007 they work much longer. The share of those who work more than 60 hours per week has increased by 4.7 % to reach more than 15% in 2007.

Table 3. Shifts in working hours per week

		All occupations					Engineers				
		Persons (1000)	～34 hours	35～45	46～59	60～	Persons (1000)	～34 hours	35～45	46～59	60～
Total	1997	45694	8.05%	52.68%	30.49%	8.68%	2144	0.75%	51.07%	37.27%	10.82%
	2007	46051	11.59%	43.13%	31.65%	13.32%	2243	1.81%	36.53%	46.05%	15.51%
	Change	*357*	*3.54%*	*-9.55%*	*1.16%*	*4.64%*	*99*	*1.07%*	*-14.55%*	*8.78%*	*4.69%*
Male	1997	29427	2.40%	49.81%	35.87%	11.83%	1990	0.55%	50.05%	38.14%	11.26%
	2007	28458	4.29%	39.39%	38.10%	17.93%	2049	1.48%	35.18%	47.11%	16.13%
	Change	*-969*	*1.89%*	*-10.42%*	*2.23%*	*6.10%*	*59*	*0.93%*	*-14.87%*	*8.97%*	*4.87%*
Female	1997	16266	18.28%	57.86%	20.76%	2.99%	154	3.90%	64.29%	26.62%	5.19%
	2007	17593	23.40%	49.18%	21.23%	5.86%	194	5.27%	50.77%	34.81%	8.99%
	Change	*1327*	*5.12%*	*-8.68%*	*0.47%*	*2.87%*	*40*	*1.37%*	*-13.51%*	*8.19%*	*3.79%*

Source: 'Employment status survey' (Ministry of Internal Affairs and Communications)

And this forced long working hours are felt by engineers across firms and sectors. Among those engineers surveyed not only agree with this observation but also complained that this long work hour are affecting the quality of their work.

C) Decreased investment on engineers' knowledge and skill improvement

: Another consequential negative change on the engineers' performance is the decreased investment on engineers' knowledge and skill improvement. First the engineers we surveyed are too busy to spend time for self-learning as 73% of those surveyed engineers share this observation. Also the prolonged working hour have shrunk availability of experience engineers for teaching young and un-experienced engineers as more than 3 out of four engineers surveyed agreed with this statement. We also add that the change mentioned above seems not to be limited to time availability. Actually about 2 thirds of engineers feel that the supportive atmosphere of workplace for learning is disappearing.

D) Consequential Decreased work motivation of engineers

: What happened to their work motivation is probably more significant given the stronger impact of work motivation on the engineers' performance. As a result of all those changes mentioned above, the engineers work motivation has declined substantially in the last decade. As the work motivation is conditioned by various characteristics, so we show the net change of work motivation after controlling them. As we see in Table4, regardless their specialty engineers are clearly de-motivated now.

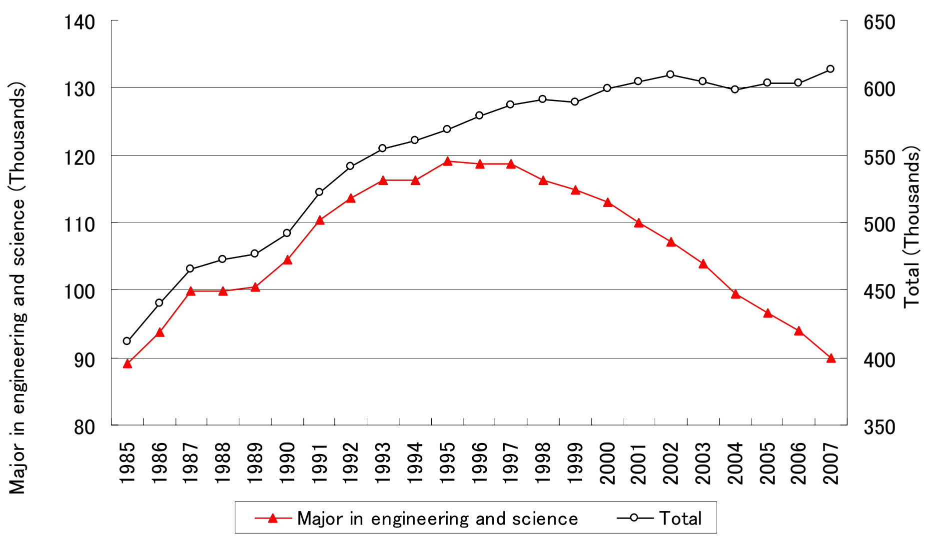
Table 4. Shifts in work motivation and company loyality by occupations (Adjusted)

Occupations	Work motivation			Company loyality		
	1994	2005	Change	1994	2005	Change
R&D	**0.45**	**0.15**	**−0.30**	**0.03**	**−0.28**	**−0.31**
System Engineers	**0.25**	**−0.09**	**−0.35**	**−0.01**	**−0.32**	**−0.31**
Production (Reference)	0.00	0.00	0.00	0.00	0.00	0.00
Clerical 1	0.21	0.26	0.05	0.32	0.08	−0.24
Clerical 2	0.03	−0.10	−0.14	0.17	0.16	−0.01
Sales	0.31	0.28	−0.02	0.14	0.25	0.11

Source: Fujimoto and Nakata (2007) Table 6, Table A2.
Note: Clerical 1 means "with more than 16 years of education."
Clerical 2 means "with less than 14 years of education."

Actually the negative emerging environment is not limited with in a domain of company. At national level, there is an important change in the size of future engineers. The number of college students majoring in engineering and science has shrunk more than 25% in the last 10 years as we can see them in Figure 4. The linkage between this decreased popularity of engineering and science and the changing environment mentioned above is not yet substantiated, but we suspect as the poor working conditions of engineers, including the above mentioned long hour and lately documented low pay, are now publicly recognized.[i] We have already started to feel this impact of the low popularity as we see the age structure of the Japanese engineers is gradually shifting to older.

Figure 4. Shift in the entrances into Japanese universities
Source: NISTEP(2008) "Digest of Japanese Science and Technology Indicators (2008 updates)"



4. Implications

We have documented that the Japanese engineers are performing quite well internationally as well as over time. And their high performance is basically realized not only because of their high ability and motivation. The work conditions as well as workplace environment are proven equally important. But those conditions and environment are changing as the management responds to the more competitive global market by reevaluating and changing the organization structure and functioning as well as human resource management. Unfortunately those management initiatives are not based on the accurate understanding of performance of engineers as well as the complex functioning of factors behind their high performance. As a result, the management initiatives have already caused some negative consequences, including deteriorating work motivation. And the impacts may well be not limited to be short-term as we receive less and less new entrants of engineering major at college.

One immediate policy implication is easily drawn from our observations. Japan needs a new source of capable engineers to off-set the shrinking pool. And Japan does posses two untapped sources. One is older engineers. The other is female engineers. All the Japanese regular employees have to retire once they reach a compulsory retirement age, which is generally set between 60 and 65. But the life-expectancy is hovering around 80 for male and 85 for female; retirement at age before 65 is nothing but a waste of human resources. Secondly the female students occupy only 10.7% of engineering major at Japanese colleges. This is a sharp contract of majority of female students in medicine. Therefore, by increasing female students' share in engineering major, we can secure a new but stable source of future engineers in the years to come. We do remind those who can initiate actions to tap those two underutilized resources that the full utilization needs a bold re-programming of their human resource management. The Japanese companies are not treating those people, old and/or female. As we can learn from Table 5, the Japanese firms discriminate against old and/ or female engineers despite the fact they, the older, are either more productive than other or the female engineers are equally productive as male counter-parts. Any efforts to tap those scarce resources should start from here.

Table 5 The effects of factors (variables) for performance and treatment

Factors	Variable	For treatment	For performance
Individual characteristics	Female	−	
	Age	−	+
Ability	Education	(+)	+
	Self-evaluated competency	+	+
Motivation	Company loyality	+	
	Work motivation		+
Job characteristic	Job matching		+
	Over-time working hours	+	+
	Job discretion		+
	Important job	+	+
Workplace enviroment	Good human relationship	+	+
	Open/Pro-active atomosphere	+	+
Company characteristic	R&D sale ratio change		(+)
Performance	Performance	+	

Note: "+" means positive effect and "(+)" means positive effect with using only 'work motivation' as motivation factor. "−" means negative effect. We use 10% significance level. This estimate is limited in the data belong to Performance-based HRM companies.

Footnotes:

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i See Nakata(2009).

Reference:

Nakata, Yoshifumi(2009),"Japanese Engineers' Pay: Compared to the U.S." (Nichibei -Hikaku demita Gijyutsusha no Chingin), Denki Rengo NAVI, No.25, May-June, pp.16-24.

Fujimoto, Tetsushi. and Yoshifumi Nakata(2007), "Has work motivation among Japanese workers declined? " *Asian Business and Management*, Vol.6, No. S1, pp.S57-S88.