

Co-ordination between R&D and Human Resource in the post catching-up era

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ABSTRACT

Korea has entered into the Post Catching-up era and the necessity of new innovation strategy in response is being raised. This study argues the necessity of new innovation strategy and discusses the issue of co-ordination between R&D and Human Resource for that as the key factor. From empirical analysis, there seems to be restricted inflow of outstanding human resources to manufacturing sectors and lowering effectiveness of major even with the improved compatibility between major and job. Especially, it is severe in the industries with high R&D investment. It can be interpreted as an incoordination of the technological innovation efforts from the aspect of R&D investment with human resource utilization from the aspect of new human resource. The analytical result and interpretation suggests that there should be more active improvement on the co-ordination between innovative manufacturers' efforts and human resource utilization, in order to keep sustainable development.

Key words: Co-ordination, R&D, usefulness of major for work, analysis of Input/Output, wage analysis for the engineering graduate.

1. RAISING ISSUES

Korea has gone through a successful catching-up process and reached the stage to build new innovation system after year 2000. But this kind of awareness and raising issue has been remained at normative and declaratory level, and direction and policy based on theoretical foundation and proof analysis have not proceeded([1]-[2]). To this matter, this study tries to verify the stagnation of R&D input result and the necessity of new innovation policy, and to demonstrate the immediate need of new innovation policy from the perspective of co-ordination between R&D and human resource.

The issues and assertion raised by this study focus on emphasizing the co-ordination with R&D investment more as the core element of innovation system in the aspect of process surrounding national scale knowledge forming & utilizing, which is the another aspect of national innovation system. That has a priority over restructuring the system through element improvement of innovation system such as an increase of R&D investment, in order to achieve transition to post catching-up type innovation system from catching-up innovation system, which is based on the mechanism of imitative learning. In order to verify that, this study tries to carry out changes on R&D output requirements effect by industry based on 'Input-Output table' & attached 'Employment table', usefulness effect between major and job in wage function (especially focusing on engineering school) of university graduates using 'Graduates Occupational Mobility Survey (GOMS)', and

exploratory analysis on knowledge influx and utilization per industry by linking above changes and effects.

In theoretical aspect, this study is an extension of research stream for National Innovation System. The studies on National Innovation System include firstly formation and the natural development of National Innovation System's composing elements such as government-university-enterprise-financial institute with focus on institutional structure, exemplified in Freeman[3] from Great Britain with explanation on Japanese production system by focusing on evolutionary aspect and Nelson[4] with explanation on American technological development. Secondly, there is another type of technological innovation theory of Lundvall[5] and Edquist[6] in Europe who paid less attention on the composing elements of national innovation system by emphasizing learning process aspect through user-producer interactions. While the general study current is divided into institutional structure and learning process, study current that emphasizes systematic structure had been deployed into regional innovation system or industry innovation system according to analysis level. The stream of innovation policy in Korea also had emphasized this systematic structure. In the aspect in which the analysis on the development of corporate innovation ability proceeds mainly with innovation achievements such as R&D, and additionally focusing on the institutional-structural connection with national policy and overseas export, it can be classified as institutional structure. This kind of classification standard is same in Kim[7], but Kim[8] developed the discussion mainly on learning process.

In contrast with regional innovation system which has discussed innovation policy focused on the role of university-

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Manuscript received Jul. 12, 2012; revised Sep 7, 2012;
accepted Sep 17, 2012

enterprise-government, this study will focus on learning process. This is to emphasize the qualitative side of Human Resource rather than quantitative side. In this context, learning process is an aspect of Human Resource, and when innovation efforts from each industry coordinate successfully with this learning process, the expected innovation achievements can be realized. Especially, while the method of creating knowledge has changed from Mode 1 to Mode 2 in the middle of spreading convergence technology([9]-[11]), the imitation based skill forming strategy in Catching-up period reached its limit and therefore, building new human resource policy is necessary in the post catching-up era. Viotti[12] conceptualized the innovation-learning systems of latecomer catching-up countries as National Learning System (NLS). This study tries to prove the necessity of building new National Learning System (NLS) in the context of Co-ordination among R&D human resources in Post Catching-up stage.

This study will present that the ripple effect of R&D on output and employment has been stagnated even with the increase of R&D input when looking into the Input-Output table of 2005, 2007 and 2009 in the chapter 2. In the chapter 3, the wage effect of usefulness between major and job of newly graduates of engineering school is analyzed at the level of 28 industry classification by using GOMS data, in which usefulness effect between major and job had declined while passing 2008-2010. In the aspect of wage as the proxy variable of output and productivity, this receding usefulness between major and job could be a cause to R&D effect stagnation in the previous chapter. The analysis done in the chapter 2 and 3 are combined in the chapter 4, while presenting the possibility of realizing expected innovation achievement when the learning process focusing on Human Resource aspect successfully coordinate with innovation efforts. The achievement, limitation and following subject are discussed in the chapter 5.

2. R&D RIPPLE EFFECT IN POST CATCHING-UP ERA

The key of technological innovation in the post catching-up stage has to be something that goes beyond imitation [8], and the importance of R&D for that matter is emphasized more and more. This ripple effect of R&D to the entire industry can be displayed through Input-Output table. The basic structure of Input-Output matrix is as below.

$$AX + Y - M = X$$

A: input coefficient,

X: industry output,

Y: final demand,

M: exports

When resolve this for *X*, $X = (I - A)^{-1}(Y - M)$ is the result, and $(I - A)^{-1}$ is called Leontief inverse matrix or total requirements matrix.

Table 1. Total requirements table

	Industry 1	Industry 2	Industry 3	Industry 4
Industry 1	r_{11}	r_{12}	...	S_1
Industry 2	r_{21}	:	...	
Industry 3	:	:		
Column total	R_1	...		

Table 2. R&D Input coefficient by Industry (%)

Product	2005	2007	2009
Agriculture, forestry and fisheries	.024	.031	.028
Mining and quarrying	.049	.049	.055
Food and beverages	.133	.174	.174
Textiles, textile and leather	.097	.125	.130
Wood, cork, pulp and paper	.142	.231	.244
Printing and publishing	.337	.472	.458
Coal and refined petroleum	.115	.224	.167
Chemicals and chemical	.145	.361	.511
Other non-metallic mineral	.529	.644	.708
Basic metals	.627	.895	.022
Fabricated metal	.366	.488	.526
Machinery	.567	.907	.124
Electrical equipment	.919	.627	.747
Optical equipment	.232	.815	.073
Transport equipment	.856	.029	.085
Other manufacturing	.426	.503	.447
Electricity, gas and water supply	.252	.566	.713
Construction	.484	.606	.626
Wholesale and retail trade	.096	.128	.153
Hotels and restaurants	.008	.010	.012
Transport and storage	.152	.173	.159
Post and telecommunications	.903	.251	.260
Finance and insurance	.115	.151	.173
Real estate and Business service	.511	.592	.592
Public admin and defense	.673	.859	.248
Education and health	.124	.122	.116
Other social and personal services	.030	.038	.033
Other	.016	.022	.022
Total industry	.909	.050	.122

Source: Calculated by reconstructing yearly I/O from Bank of Korea[13]

At this moment, the output increase in A industry required by a final demand unit for A industry is r_{11} , and the output increase in A industry required by a final demand unit for B industry is r_{12} . Output increase of A industry required by the final demand from each industry is presented as Row total S_1 , and it is called Forward Linkage. Column total R_1 is a ripple effect to the final demand of A industry which is also called Backward Linkage.

Meanwhile, in the types of Total output multiplier, there are $(I - A)^{-1}$ type that is based on input coefficient of transaction table at producer's price in total competition import type and $(I - A^d)^{-1}$ type that distinguishes domestic and import (A^d here is input coefficient matrix of domestic transaction table). A conventionally Total is calculated from $(I - A^d)^{-1}$,¹⁾ with

¹⁾ Some say that $(I - A^d)^{-1}$ is more appropriate than $(I - A)^{-1}$ because $(I - A)^{-1}$ expands Total effect more than $(I - A^d)^{-1}$, and contribution to production elements is same regardless of the source of production elements either in domestic or overseas. But this study used $(I - A^d)^{-1}$ following conventional analysis cases. For detail understanding, see Miller and Blair

which Employment multiplier²⁾ appears as $\hat{l}(I - A^d)^{-1}$ (in here, \hat{l} is employment coefficient). Total output multiplier and Employment multiplier by R&D investment can be acquired from Modified transaction table \hat{A}^d , which is an exogenous specification of the R&D sector. R&D input coefficient of each industry is presented in <Table 2>. This is drawn from Integrated transaction table at producers' price according to 2005 Constant price with modification on 28 areas. While Precision instruments, Electric & electronic and Communication & broadcasting had large R&D input coefficient, overall R&D input coefficient had increased.

When looking into the impact of R&D investment on Total output <Table 3> by using Domestic transaction table, which is an exogenous specification R&D sector and modified 28 areas from Domestic transaction table of Midium classification³⁾, this table presents production amount directly and indirectly required to satisfy a 1 R&D demand unit increase for a certain industry. The impact of changes in final demand of R&D on Total output for Basic metals and Chemical industry appeared to be the highest, followed by Real estate and business service. In the trend of the impact of R&D on Total output by industry, most of impact by R&D demand had decreased or stagnated, while the simple average of entire economy appeared to be 1.908 in 2005, 1.893 in 2007 and 1.903 in 2009. The impact of R&D on Employment can be acquired by comparing Employment inducement coefficient (from Employment multiplier) with Employment coefficient <Table 4>, among which Coal and refined petroleum industry, Basic metals and Electricity, gas and water supply had large impacts. But the overall decrease of this impact is interesting. When looking into the trend of impact of changes in R&D demand on Employment, the margin of decrease of Employment inducement coefficient by R&D demand is larger than the overall decrease margins of Employment coefficient, while the simple average of entire economy appeared to be dropping continuously as of 5.48 in 2005, 4.66 in 2007 and 4.56 in 2009.

Even though overall R&D input coefficient by industry has increased, impact of R&D demand on Total output has decreased or stagnated along with continuous decrease impact on Employment inducement, which raises a necessity of consideration for complementary measures on R&D in Post catching-up era. To respond on that matter, this study will focus on human resource aspect as a complementary measure for R&D.

Table 3. Output change by the change of R&D demand

	2005	2007	2009
Agriculture, forestry and fisheries	1.912	1.879	1.894
Mining and quarrying	1.159	1.126	1.118
Food and beverages	2.103	2.078	2.099
Textiles, textile and leather	1.599	1.561	1.554

[14].

2) Employment in Industry relation table means both employed and employee. Employed includes employee, self-employed and unpaid family worker. Employee is composed of regular worker, temporary worker and daily hire as wage laborers.

3) The reason to use Domestic transaction table differently from R&D input coefficient is that this study draws impact on Total requirements based on $(I - A^d)^{-1}$ as mentioned earlier.

Wood, cork, pulp and paper	1.998	2.019	2.061
Printing and publishing	1.320	1.286	1.281
Coal and refined petroleum	2.440	2.311	2.271
Chemicals and chemical	3.650	3.575	3.485
Other non-metallic mineral	1.441	1.444	1.429
Basic metals	3.788	3.638	3.800
Fabricated metal	1.817	1.810	1.759
Machinery	1.693	1.748	1.757
Electrical equipment	1.938	1.928	1.945
Optical equipment	1.135	1.157	1.189
Transport equipment	1.819	1.847	1.767
Other manufacturing	1.186	1.244	1.262
Electricity, gas and water supply	2.071	2.030	2.022
Construction	1.187	1.155	1.144
Wholesale and retail trade	2.512	2.484	2.532
Hotels and restaurants	1.919	1.938	1.982
Transport and storage	2.231	2.183	2.163
Post and telecommunications	1.727	1.742	1.738
Finance and insurance	2.280	2.363	2.543
Real estate and Business service	2.975	2.928	2.929
Public admin and defense	1.037	1.024	1.030
Education and health	1.191	1.202	1.236
Other social and personal services	1.366	1.446	1.432
Other	1.920	1.862	1.854
Average	1.908	1.893	1.903

Source: Calculated by reconstructing yearly I/O from Bank of Korea[13]

Table 4. Employment change by the change of R&D demand

	Employment coefficient			Employment inducement coefficient			Employment inducement coefficient/ Employment coefficient		
	2005	2007	2009	2005	2007	2009	2005	2007	2009
Agriculture, forestry and fisheries	.0426	.0393	.0352	.0536	.0496	.0450	1.26	1.26	1.28
Mining and quarrying	.0054	.0058	.0056	.0062	.0063	.0061	1.15	1.10	1.10
Food and beverages	.0039	.0037	.0035	.0200	.0197	.0193	5.15	5.26	5.54
Textiles, textile and leather	.0086	.0079	.0078	.0139	.0125	.0123	1.62	1.58	1.57
Wood, cork, pulp and paper	.0052	.0048	.0047	.0133	.0131	.0128	2.57	2.71	2.73
Printing and publishing	.0089	.0111	.0098	.0119	.0140	.0124	1.33	1.26	1.27
Coal and refined petroleum	.0002	.0002	.0002	.0132	.0112	.0106	72.49	51.28	47.69
Chemicals and chemical	.0027	.0025	.0024	.0248	.0229	.0215	9.16	9.32	8.87
Other non-metallic mineral	.0043	.0038	.0036	.0072	.0066	.0062	1.67	1.74	1.73
Basic metals	.0010	.0010	.0011	.0149	.0135	.0151	14.70	12.95	13.62
Fabricated metal	.0066	.0064	.0071	.0124	.0119	.0123	1.87	1.86	1.75
Machinery	.0050	.0042	.0047	.0095	.0088	.0094	1.92	2.07	2.00
Electrical equipment	.0032	.0025	.0021	.0092	.0078	.0072	2.84	3.17	3.47
Optical equipment	.0072	.0056	.0055	.0081	.0066	.0067	1.13	1.18	1.22
Transport equipment	.0029	.0027	.0030	.0082	.0081	.0081	2.87	3.00	2.67
Other manufacturing	.0081	.0068	.0069	.0096	.0087	.0090	1.19	1.28	1.30
Electricity, gas and water supply	.0015	.0014	.0014	.0096	.0086	.0086	6.44	6.04	6.22
Construction	.0105	.0107	.0103	.0121	.0120	.0116	1.16	1.12	1.13
Wholesale and retail trade	.0254	.0246	.0261	.0386	.0365	.0382	1.52	1.48	1.46
Hotels and restaurants	.0247	.0238	.0235	.0291	.0281	.0280	1.18	1.18	1.19

Transport and storage	.0121	.0112	.0114	.0226	.0210	.0209	1.86	1.87	1.84
Post and telecommunications	.0031	.0029	.0027	.0095	.0094	.0093	3.06	3.17	3.43
Finance and insurance	.0062	.0055	.0052	.0177	.0169	.0184	2.84	3.10	3.54
Real estate and Business service	.0071	.0069	.0085	.0263	.0249	.0265	3.70	3.59	3.13
Public admin and defense	.0102	.0095	.0101	.0104	.0097	.0103	1.03	1.02	1.02
Education and health	.0160	.0163	.0163	.0180	.0183	.0186	1.12	1.12	1.14
Other social and personal services	.0176	.0166	.0175	.0208	.0202	.0208	1.19	1.21	1.19
Other				.0094	.0084	.0084			
Average	.0093	.0088	.0087	.0167	.0158	.0157	5.48	4.66	4.56

Source: Calculated by reconstructing yearly I/O from Bank of Korea[13]

3. CONNECTIVITY BETWEEN UNIVERSITY MAJOR AND WORK: FOCUSING ON WAGE FUNCTION

This chapter focuses on Human Resource as a complementary measure for R&D, while analyzing the wage of new university graduate, compatibility of major-industry and usefulness of majored curriculum at the level of 28 industry classifications mentioned earlier. Data used for that purpose includes the wage information⁴⁾ of 10,636 persons from 2008 survey on 2005 graduates in Graduates Occupational Mobility Survey (GOMS)⁵⁾, and 7,908 persons with income among 2007 university graduates surveyed on 2010. Also grade data which is a critical factor in wage function estimation of university graduate is combined together. Grade data of individual⁶⁾ was drawn from internal data of Jinhaksa for nationwide yearly grade data by university & department. This study used 2001 entry grade data for 2005 graduates and 2003 data for 2007 graduates. Grade data employed average score of each university and department calculated as 100 percentile of nationwide score, and included distinction of campus such as main and branch campuses.⁷⁾

4) It should be income instead of wage in strict sense because it includes self-employed beside of employee, but it became wage information because it did not include financial earnings. Meanwhile, the education division of university in this study is distinguished from separate Educational universities. The average monthly income of 3rd year Educational university graduate in 2010 was 2.21 million won, whereas that of 3rd year Vocational college graduate was 2.02 million won.

5) Refer to <http://survey.keis.or.kr> for introduction and data of Graduates Occupational Mobility Survey (GOMS)[15].

6) Dr. Yim, Un's help was absolutely critical in grade data utilizing and for detailed items of grade data, refer to the chapter 7 of 「Socio-economic achievement & limitation of higher education」 by Kim et al.[16]. In the process of using grade data, some universities without the grades of departments were eliminated, and therefore, the sample size of Engineering in Table 5 and Table 6, which had not use grade data, doesn't match with the sample size of Engineering in Table 7, which had used grade data. But the average income of total sample by school without grade data doesn't have much difference with the average income of reduced samples by school. And the estimated result of wage function without grade data is consistent in overall aspect with the estimated result of wage function with grade data excluding the items for grade data.

7) Some universities' departments in the graduates' departments in GOMS are not concurrent with the departments in the grade data provided by Jinhaksa, which cases are regarded as related department or department in similar school.

Table 5. Average monthly income (After 3 years from graduation)

(Unit: person, 10k won)

Major Filed	2008		2010	
	Sample size	Average monthly income	Sample size	Average monthly income
Liberal arts	1,278	197.8	1,066	205.9
Social science	2,763	228.9	1,751	230.9
Education	589	199.7	532	203.5
Engineering	3,332	245.1	2,228	251.6
Science	1,482	199.7	1,194	220.6
Medical	397	249.9	336	260.5
Art & athletic	795	186.1	801	184.6
Total	10,636	222.1	7,908	226.5

Source: Drawn from GOMS 2005-3, 2007-3 data[15]

The average monthly income of 3rd-year university graduate came out to be 2.221 million won in 2008 and 2.265 million won in 2010. Against that, to identify the effect by grade, gender, major, enterprise size and industry, the estimated results of wage functions are presented in table 6. While the wage effect of grade is significant, all the school name value effects are controlled in wage function estimation. Female has significantly lower wage than male, and as the enterprise size is larger, the wage was higher. Wage effect by major also displays significant result except Social science division. When comparing the wage effect by industry with Machinery industry as the basis, Finance & insurance has the highest effect. Coal and refined petroleum, Electricity, gas and water supply, Electrical equipment and Transport equipment had significantly higher wage effects than Machinery industry, while Education & health service, Public administration, Social & personal service and Food & lodging had significantly lower wage effects than Machinery industry.

The interesting thing in this study is the effects of 'compatibility between work and major' and 'usefulness between work and major'⁸⁾ to wage, rather than wage effect of major or industry itself. 'Compatibility between work and major' had decreased in 2010 from 2008 but instead, the effect of 'usefulness between work and major' to wage became significant. It is necessary to analyze more on the effects of 'compatibility between work and major' and 'usefulness between work and major' to wage by major.

To follow the purpose of this study, rather than targeting all the departments, this study will focus on Engineering school. Because Natural science departments such as Physics and Chemistry have not high direct relationship between major and work except some part,⁹⁾ this study will focus on the limited results in Engineering school.¹⁰⁾ (A) Major dummy analysis displays estimated wage function results of newly employed Engineering school graduate (3 years after graduation), while

8) The case of answering yes on usefulness between work and major among the cases of yes answer on usefulness between work and major is 1, and all others are 0.

9) This can be verified in a separate analysis.

10) Some difficult to include departments into major classification in Engineering school. And used modified sample with 2,781 persons (83%) among 3332 persons of 2008 Engineering school wage analysis sample, and 1783 persons (80%) among 1783 persons of 2010 Engineering school sample.

(B) work-major compatibility analysis was estimated by having major compatibility as a variable instead of major dummy and processing the work-major usefulness with separate dummy variable. (C) Work-major usefulness analysis employed major usefulness by major as a variable.¹¹⁾

Table 6. Estimated wage functions of newly employed (After 3 years from graduation)

Independent variable: Log(Average monthly income)	2008		2010		
	Estimated coefficient (Pr > t)		Estimated coefficient (Pr > t)		
Constant term	5.508	<.0001***	5.541	<.0001***	
Gender (Male=0)	-0.179	<.0001***	-0.148	<.0001***	
School (Engineering =0)	Liberal arts	-0.042	0.002***	-0.064	<.0001***
	Social science	0.011	0.282	-0.012	0.302
	Education	0.140	<.0001***	0.062	0.001***
	Science	-0.058	<.0001***	-0.034	0.009***
	Medical	0.241	<.0001***	0.223	<.0001***
	Art & athletic	-0.076	<.0001***	-0.133	<.0001***
	Industry (Machinery industry=0)	Agriculture, forestry and fisheries	-0.043	0.649	-0.005
Mining and quarrying		0.117	0.449	0.156	0.430
Food and beverages		0.002	0.964	-0.069	0.087*
Textiles, textile and leather		-0.051	0.207	-0.049	0.187
Wood, cork, pulp and paper		-0.020	0.756	-0.022	0.816
Printing and publishing		-0.048	0.738	-0.182	0.058*
Coal and refined petroleum		0.192	0.015**	0.143	0.100*
Chemicals and chemical		0.062	0.018**	0.031	0.235
Other non-metallic mineral		0.017	0.791	0.027	0.665
Basic metals		0.008	0.892	0.101	0.035**
Fabricated metal		-0.079	0.072*	-0.080	0.093*
Machinery		0.061	0.005***	0.072	0.004***
Electrical equipment		0.014	0.773	-0.055	0.186
Optical equipment		0.070	0.010***	0.082	0.002***
Transport equipment		-0.065	0.238	-0.064	0.326
Other manufacturing		0.138	0.000***	0.130	0.003***
Electricity, gas and water supply		0.049	0.040**	0.031	0.206
Construction		0.050	0.019**	0.023	0.272
Wholesale and retail trade		-0.098	0.003***	-0.096	0.008***
Hotels and restaurants		0.085	0.003***	0.059	0.068*
Transport and storage	-0.016	0.651	0.051	0.196	

11) In the process of setting major usefulness by major as a variable, when estimating major compatibility by processing with dummy variable, no meaning result appeared. Therefore, only the analysis result that removed that at final stage is presented. With a same reason, major dummy also presents the result after removing (A) work-major compatibility analysis (B) work-major usefulness analysis, which displayed no meaningful result in analysis process. Meanwhile, the effects of industry and enterprise size were omitted because they were similar with the wage function estimate result of entire new employed in the earlier part.

	Post and telecommunications	0.253	<.0001***	0.202	<.0001***
	Finance and insurance	-0.013	0.480	-0.007	0.686
	Real estate and Business service	-0.217	<.0001***	-0.198	<.0001***
	Public admin and defense	-0.252	<.0001***	-0.222	<.0001***
	Education and health	-0.164	<.0001***	-0.177	<.0001***
Enterprise size (Over 300=0)	1~4	-0.354	<.0001***	-0.204	<.0001***
	5~9	-0.278	<.0001***	-0.207	<.0001***
	10~99	-0.147	<.0001***	-0.130	<.0001***
	100~299	-0.106	<.0001***	-0.090	<.0001***
Compatibility between work-major (Not compatible = 0)		0.083	<.0001***	0.048	<.0001***
Usefulness between work-major (Not useful = 0)		0.014	0.112	0.017	0.058*
F Value		117.060		72.180	
Pr > F		<.0001***		<.0001***	
Adj R-Sq		0.299		0.260	

Note: Pr > |t| < 0.01 is ***, Pr > |t| < 0.05 is **, Pr > |t| < 0.1 is *

Firstly, (A) when considering major dummy (Mechanical engineering as basis), work-major usefulness and work-major compatibility altogether in major dummy analysis (standard row), except Chemical engineering, wage difference by major was shown significantly. The wage level by major in 2010 displays the order of Mechanical > Electric & electronics > Source Material > Civil engineering > Construction from the highest. More interesting wage effects of work-major compatibility and work-major usefulness had positive effect of work-major compatibility in 2008 but significantly positive effect of work-major usefulness in 2010.

(B) In the result of major compatibility analysis by detailed major, major compatibility had positive effect on wage in Civil engineering, Mechanical engineering, Electric & electronics engineering, Computer science and Chemical engineering in 2008, while no significant major compatibility effect in overall aspect. In 2010, work-major usefulness was not statistically significant for all the majors, while overall major usefulness had positive effect. (C) In the result of major usefulness analysis by detailed major, only the major usefulness effect of Mechanical engineering had positive effect in 2008. In 2010 also, only the major usefulness effect of Mechanical engineering had positive effect, with seemingly increased effect from 2008, all other majors had not statistically significant effect of major usefulness by detailed major.

Even though influencing factors to wage in the detailed majors of Engineering school is being shifted to work-major usefulness from work-major compatibility, the effect of work-major usefulness in detailed major is being delayed.¹²⁾ When wage is regarded as representative index for productivity, the wage effect of work-major usefulness can be an effect for productivity of work-major usefulness, and the improvement for work-major usefulness is being stagnated. It can be interpreted as a retreat in overall aspect of connectivity between

12) Analysis result in above and its interpretation are in rough status. In relation with that, more strict analysis with from detailed research remains as following study subject.

Human Resource and work.

Table 7. Major compatibility & usefulness effects of New Engineering school graduate employed (3 years after graduation)

	(A) Major dummy (Mechanical=0)				(B) Major compatibility dummy by major (No compatibility=0)				(C) Major usefulness dummy by major (No usefulness=0)				
	2008		2010		2008		2010		2008		2010		
	Estimated coefficient (Pr > t)		Estimated coefficient (Pr > t)		Estimated coefficient (Pr > t)		Estimated coefficient (Pr > t)		Estimated coefficient (Pr > t)		Estimated coefficient (Pr > t)		
Constant term	4.672	<.0001***	5.282	<.0001***	4.640	<.0001***	5.288	<.0001***	4.664	<.0001***	5.296	<.0001***	
Grade	0.002	<.0001***	0.001	<.0001***	0.002	<.0001***	0.001	<.0001***	0.003	<.0001***	0.001	<.0001***	
Gender (Male=0)	-0.104	<.0001***	-0.123	<.0001***	-0.107	<.0001***	-0.123	<.0001***	-0.110	<.0001***	-0.124	<.0001***	
Major occupational category	Architectural	-0.047	0.065*	-0.044	0.086*	0.041	0.116	-0.032	0.255	0.012	0.636	0.023	<.0001***
	Civil engineering	-0.023	0.357	-0.024	0.392	0.051	0.054*	-0.015	0.630	0.013	0.624	0.023	0.494
	Mechanical					0.073	0.002***	0.023	0.373	0.022	0.344	0.038	0.528
	Electric/electronics	-0.030	0.260	-0.042	0.136	0.045	0.032**	-0.023	0.313	0.004	0.839	0.006	0.257
	Source/material	-0.037	0.054*	0.014	0.466	0.013	0.660	-0.025	0.435	-0.017	0.595	0.018	0.838
	Computer/telecommunication	0.039	0.188	0.004	0.902	0.056	0.004***	0.016	0.439	0.029	0.089*	0.030	0.678
	Chemical	0.039	0.188	0.004	0.902	0.121	0.000***	0.014	0.682	0.092	0.014**	0.058	0.218
	Work-major usefulness (No usefulness=0)	-0.001	0.915	0.026	0.079*	-0.002	0.894	0.031	0.032**				
Work-major compatibility (No compatibility =0)	0.058	0.001***	0.010	0.584									
F Value	37.90		19.54		37.82		19.47		38.26		19.75		
Pr > F	<.0001***		<.0001***		<.0001***		<.0001***		<.0001***		<.0001***		
Adj R-Sq	0.35		0.28		0.35		0.28		0.35		0.28		

Note: Pr > |t| < 0.01 is ***, Pr > |t| < 0.05 is **, Pr > |t| < 0.1 is *

4. ISSUE OF CO-ORDINATION BETWEEN R&D AND HUMAN RESOURCE

Since the assertion, saying that technological development and workforce (in skill level aspect) are complementary to each other, was raised in the complementarity hypothesis of Griliches[17], many empirical analyses for skill-based technology has been studied[18]. Also there is adaptation hypothesis by Nelson and Phelps[19], in which a human capital in appropriate level precedes to adoption of new technology. That is a classic discussion on the relation between technological development and human capital along with Griliches' complementarity hypothesis.

On the basis of these hypotheses, it can be predicted that R&D input should co-ordinate with outstanding human resources for improved achievement. Therefore, in response to R&D input increase, utilizing and recruiting outstanding human resources should be planned. For that matter, this chapter will review 'Connectivity with work' of new workforce by wage level and industry for influx of new outstanding human resources by industry in the aspect of co-ordination between R&D and appropriate human capital utilization.

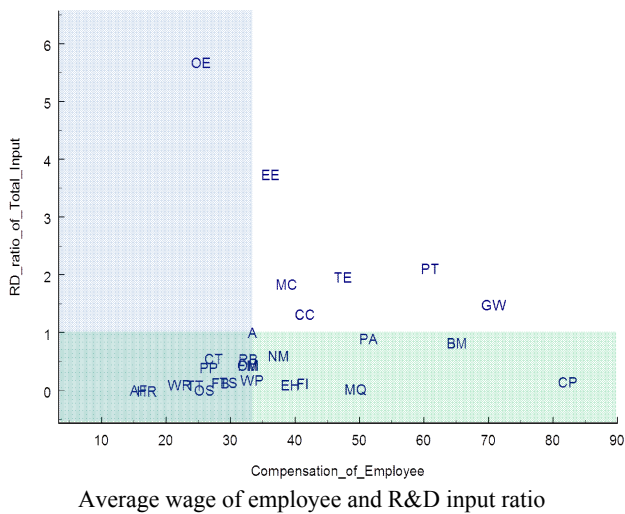
Before using Graduates Occupational Mobility Survey (GOMS) data, reviewing the changing trend of employee average wage by industry on the constant price of 2005 by

using Input-Output table and attached Employment table, is useful for following analysis. Analysis on the difference in changing pattern by industry and difference in rate of change should be reviewed separately. In this chapter, the average figure in 3 period of average wage of employee by industry is presented in the 4-quadrant of [Picture 1] along with the average figure of R&D input rate by industry in 3 period.¹³⁾

The 1st quadrant displays above the average employee average wage and R&D input rate, and the industries in this area have high R&D input along with easy recruiting of quality HR. Chemicals and chemical (CC), Electrical equipment (EE), Transportation equipment(TE), Electricity, gas and water supply (GW) and Post and telecommunications (PT) belong to this area. The 2nd quadrant has high R&D input but lower employee average wage than entire industry average. This is a area with difficulty for securing quality HR compared to R&D, having a possibility of discordance between technology and HR. Precision instruments belong to this area. The 3rd quadrant has low R&D input and low attraction to quality HR, being interpreted as relatively lagged behind area in technological

¹³⁾ When comparing the yearly average employee wage and R&D input rate by industry, Electrical equipment(EE), Electricity, gas and water supply(GW) and Post and telecommunications (PT) displays rightward migration (average wage increase), while Other social and personal services (OS) displays upward migration (R&D input rate increase).

innovation aspect. Agriculture, forestry and fisheries (AF), Food and beverages (FB), Textiles, textile and leather (TT), Printing and publishing (PP), Fabricated metal (FM), Other manufacturing (OM), Construction (CT), Wholesale and retail trade (WR), Hotels and restaurants (HR), Transport and storage (TS), Real estate and Business service (RB) and Other social and personal services (OS) belong to this area. The 4th quadrant has low R&D input but high average employee wage, having possibility of low efficiency on Human Resource, which has another meaning of possibility for discordance between technology and HR. Mining and quarrying (MQ), Wood, cork, pulp and paper (WP), Coal and refined petroleum (CP), Other non-metallic mineral (NM), Basic Metals (BM), Financial and insurance (FI), Public admin and defense (PA) and Education and health (EH) belong to this area.



Average wage of employee and R&D input ratio

With this distinction of 4-quadrants, an interpretation for that is made by comparing the average monthly wage of newly employed university graduate in different time period which was derived from GOMS data <Table 8>. In the 1st quadrant, except Post and telecommunications (PT), wage increase rate is similar or lower than the average, rendering suppressed influx of quality HR. Especially the wage of Chemicals and chemical (CC) has decreased. In the 2nd quadrant, Optical equipment (OE) has wage decrease with worsened inflow of quality HR. 3rd quadrant also displays low wage in overall, with suppressed wage increase below the average. The 4th quadrant displays getting higher overall wage level which is already higher than other areas (but Coal and refined petroleum (CP) displays wage decrease), making its Human Resource efficiency doubtful from the perspective of entire economy.

Table 8. Classification of Newly employed university graduate(within 3 years from graduation) 's wage and R&D input ratio on Fig. 1

classification	IO 28 industry classification	2008	2010	Average yearly increase rate
1st quadrant	Chemicals and chemical (CC)	251.7	248.1	-0.007
	Machinery (MC)	238.7	240.7	0.004

	Electrical equipment (EE)	268.9	275.5	0.012
	Transportation equipment (TE)	273.9	283.1	0.017
	Electricity, gas and water supply (GW)	283.7	286.8	0.005
	Post and telecommunications (PT)	232.1	254.4	0.047
	Average	258.2	264.8	0.013
2nd quadrant	Optical equipment (OE)	238.0	233.8	-0.009
3rd quadrant	Agriculture, forestry and fisheries (AF)	202.7	240.5	0.089
	Food and beverages (FB)	228.0	227.5	-0.001
	Textiles, textile and leather (TT)	200.0	212.0	0.029
	Printing and publishing (PP)	180.9	185.8	0.014
	Fabricated metal (FM)	209.5	211.8	0.006
	Other manufacturing (OM)	209.6	212.6	0.007
	Construction (CT)	247.9	252.3	0.009
	Wholesale and retail trade (WR)	232.2	234.5	0.005
	Hotels and restaurants (HR)	203.0	202.9	0.000
	Transport and storage (TS)	251.7	251.9	0.000
	Real estate and Business service (RB)	228.7	233.3	0.010
	Other social and personal services (OS)	190.2	194.9	0.012
	Average	215.4	221.7	0.015
4th quadrant	Mining and quarrying (MQ)	258.5	283.3	0.047
	Wood, cork, pulp and paper (WP)	222.5	238.5	0.035
	Coal and refined petroleum (CP)	308.6	303.2	-0.009
	Other non-metallic mineral (NM)	226.8	240.8	0.030
	Basic metals (BM)	249.2	279.6	0.059
	Finance and insurance (FI)	297.3	280.8	-0.028
	Public admin and defense (PA)	184.2	197.6	0.036
	Education and health (EH)	179.4	188.8	0.026
Average	240.8	251.6	0.022	
Average of total (a)		233.3	240.6	0.016

Source: Drawn from GOMS 2005-3, 2007-3 data

In 'Work-major Compatibility'¹⁴⁾ The 1st quadrant displays major compatibility of average 0.8 in 2008 and average 0.76 in 2010, which is high major compatibility but receding in overall major compatibility. Major compatibility has grown only in Electrical equipment industry. Optical equipment industry in the 2nd quadrant displays increase in major compatibility with high major compatibility of 0.79 in 2008 and 0.84 in 2010. 3rd quadrant displays not high major compatibility in overall. Its major compatibility had increased from average 0.67 in 2008 to average 0.69 in 2010 but in major compatibility of detailed major had decreased. 4th quadrant displays generally high major compatibility and in increasing trend but some industries with lower major compatibility had decreased in

¹⁴⁾ In range of Maximum is 1 and that of Minimum is 0.

major compatibility.

Table 9. 'Work-major compatibility' of newly employed university graduate (Within 3 years from graduation)

classification	IO 28 industry classification	2008	2010	annual growth rate
1st quadrant	Chemicals and chemical (CC)	0.84	0.71	-0.083
	Machinery (MC)	0.77	0.75	-0.013
	Electrical equipment (EE)	0.82	0.83	0.009
	Transportation equipment (TE)	0.76	0.74	-0.015
	Electricity, gas and water supply (GW)	0.88	0.85	-0.013
	Post and telecommunications (PT)	0.73	0.69	-0.028
	Average	0.80	0.76	-0.024
2nd quadrant	Optical equipment (OE)	0.79	0.84	0.037
3rd quadrant	Agriculture, forestry and fisheries (AF)	0.63	0.82	0.144
	Food and beverages (FB)	0.68	0.74	0.040
	Textiles, textile and leather (TT)	0.75	0.71	-0.031
	Printing and publishing (PP)	0.43	0.38	-0.053
	Fabricated metal (FM)	0.57	0.62	0.047
	Other manufacturing (OM)	0.78	0.76	-0.014
	Construction (CT)	0.80	0.82	0.015
	Wholesale and retail trade (WR)	0.60	0.57	-0.023
	Hotels and restaurants (HR)	0.52	0.56	0.036
	Transport and storage (TS)	0.68	0.74	0.042
	Real estate and Business service (RB)	0.80	0.78	-0.008
	Other social and personal services (OS)	0.78	0.79	0.010
	Average	0.67	0.69	0.018
	4th quadrant	Mining and quarrying (MQ)	0.83	1.00
Wood, cork, pulp and paper (WP)		0.80	0.57	-0.155
Coal and refined petroleum (CP)		0.88	0.94	0.035
Other non-metallic mineral (NM)		0.78	0.78	-0.002
Basic metals (BM)		0.74	0.80	0.039
Finance and insurance (FI)		0.63	0.60	-0.032
Public admin and defense (PA)		0.69	0.64	-0.030
Education and health (EH)		0.86	0.85	-0.006
Average		0.78	0.77	-0.003
Average of total (a)		0.73	0.74	0.002

Source: Drawn from GOMS 2005-3, 2007-3 data

Meanwhile, 'Work-major usefulness' by industry had declined in overall <Table 10>, contrasting with the overall increase of 'Work-major compatibility'. 1st quadrant displays the major usefulness of average 0.48 in 2008 and average 0.34 in 2010, declining in major usefulness in all the industries. Optical equipment industry in 2nd quadrant also had decreased from 0.47 in 2008 to 0.32 in 2010. While overall major usefulness in 3rd quadrant is not high, its major usefulness had decreased from average 0.39 in 2008 to average 0.32 in 2010. All the industries in the area, except Agriculture, forestry and fisheries industry had declined in major usefulness. 4th

quadrant also displays low overall major usefulness, and it's getting even lower. Coal and refined petroleum industry was the only industry increased from 2008 at 0.5 to 2010 at 0.63.

Table 10. 'Work-major usefulness' of newly employed university graduate (Within 3 years from graduation)

classification	IO 28 industry classification	2008	2010	annual growth rate
1st quadrant	Chemicals and chemical (CC)	0.53	0.32	-0.221
	Machinery (MC)	0.45	0.27	-0.224
	Electrical equipment (EE)	0.56	0.35	-0.213
	Transportation equipment (TE)	0.45	0.30	-0.188
	Electricity, gas and water supply (GW)	0.49	0.47	-0.021
	Post and telecommunications (PT)	0.37	0.31	-0.073
	Average	0.48	0.34	-0.158
2nd quadrant	Optical equipment (OE)	0.47	0.32	-0.170
3rd quadrant	Agriculture, forestry and fisheries (AF)	0.31	0.45	0.206
	Food and beverages (FB)	0.41	0.35	-0.067
	Textiles, textile and leather (TT)	0.45	0.37	-0.088
	Printing and publishing (PP)	0.29	0.08	-0.481
	Fabricated metal (FM)	0.31	0.26	-0.091
	Other manufacturing (OM)	0.34	0.24	-0.157
	Construction (CT)	0.48	0.47	-0.017
	Wholesale and retail trade (WR)	0.34	0.19	-0.237
	Hotels and restaurants (HR)	0.27	0.21	-0.134
	Transport and storage (TS)	0.38	0.34	-0.053
	Real estate and Business service (RB)	0.56	0.42	-0.132
	Other social and personal services (OS)	0.54	0.42	-0.115
	Average	0.39	0.32	-0.097
	4th quadrant	Mining and quarrying (MQ)	0.83	0.33
Wood, cork, pulp and paper (WP)		0.43	0.29	-0.184
Coal and refined petroleum (CP)		0.50	0.63	0.118
Other non-metallic mineral (NM)		0.51	0.22	-0.347
Basic metals (BM)		0.49	0.39	-0.104
Finance and insurance (FI)		0.35	0.24	-0.181
Public admin and defense (PA)		0.42	0.30	-0.156
Education and health (EH)		0.69	0.54	-0.113
Average		0.53	0.37	-0.167
Average of total (a)		0.45	0.34	-0.138

Source: Drawn from GOMS 2005-3, 2007-3 data

In overall aspect, quality Human Resource is suppressed to flow into manufacturing sector, while usefulness of major has been lowered, even though Work-major compatibility has been improved. Especially, it was so in the industries with high R&D input. The effort for technological innovation with R&D input appears not to be co-ordinate with Human Resource. This kind of difficulty in co-ordination is limited not only to Human Resource Management of new Human Resource but displaying similar pattern in Adaptive ability development to new

technology and Appropriate locating of existing Human Resource (Relocating by industry etc.).¹⁵⁾

5. ACHIEVEMENT OF STUDY & FOLLOWING ISSUES

This study analyzed in the explorative way that the expected innovation achievement can be realized when the learning process focusing on Human Resource aspects successfully co-ordinate with Innovation efforts such as R&D. The analysis result displays restricted inflow of outstanding human resources to manufacturing sectors and lowering effectiveness of major even with the improved compatibility between major and job. Especially, it is severe in the industries with high R&D investment. And that can be interpreted as an incoordination of the technological innovation efforts from the aspect of R&D investment with human resource utilization from the aspect of new human resource. These analysis results and interpretation suggest active improvement on co-ordination by innovative manufacturers' efforts for technological innovation and human resource utilization, in order to sustain national innovation in the future.

The primary achievement of this study could be the efforts to integrate the problem of co-ordination between R&D and Human Resource being raised in theoretical dimension into national level innovation policy through analysis by industry unit. This can provide the proving ground for Co-ordination among R&D human resources in Post catching-up stage, which also expands the concept of Viotti's [12] National Learning System(NLS) in theoretical dimension. Meanwhile, this kind of analysis was acquired by cross analyzing R&D input and effect by industry through recomposing Input-Output table, and data on Work-major compatibility and usefulness using Graduates Occupational Mobility Survey (GOMS) through recomposing by industry. This creation of analysis data and searching on analysis method by using that can be called additional study achievements in the process of this study but it can also be the key contribution founding in this study.

But this study has not thoroughly verified the problem of co-ordination between R&D and Human Resource suppressing the expansion of R&D ripple effect. And the detailed analysis on the cause of this co-ordination difficulty has not been deployed. Study on co-ordination of Human Resource for technological change had been tried in Hwang[11], and the study that concurrenting that method with current study is on the way. There are the limitation of this study should be carried out by further study. For that matter, combining additional data (i.e. patent data by industry), utilizing panel data based on time series by industry, and applying industry sub-classification can be employed in the following related study.

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¹⁵⁾ Many related studies on Re-education & training of existing HR, and Mobility and relocation of existing HR among industry [13] [14], support this.

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