Evaluation of the Human Resource Development Effect for Korean National R&D Projects

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Abstract

Human resource development (HRD) is an important outcome of every national R&D projects. However, previous studies could not measure the economic HRD effect exclusively (Heo et al. (2008)). In this paper, we focused on measuring the economic effect of national R&D program from comparing the human-capital rates of return by manufacturing groups. The human-capital accumulation model developed by Mincer (1974) was adopted in terms of the rate of the researchers' investment in human capital.
The dataset used in this study was obtained from the Korean Labor & Income Panel Study (KLIPS). We use panel estimation methods, fixed-effect and Hausman-Taylor estimation methods, to control unobservable individual effect. As a result, in manufacturing group 2, which is consisted of the heavy industries, the human-capital accumulation level was highest among the three manufacturing groups and the total-industrial average. Empirical results imply that on the concept of learning by doing, the national R&D program has been successful in terms of providing the researchers with opportunities to accumulate human capital.

Introduction

Human resource development (HRD) is an important outcome of every national R&D project, but the previous studies could not measure the economic HRD effects of such projects exclusively (Heo et al. 2008). Joe (2005) applied the index and survey methods to evaluate the human-capital development effects of the national R&D projects, and Lee (1995) analyzed the human-capital stock using the labor quantity index. Kim (1998) pointed out, however, that even if the survey or index method can easily show the effects of the national R&D projects on human development, it has difficulty measuring such projects' economic HRD effects.
Human-capital development through R&D projects is important due to its learning-by-doing effect. Economists have long been interested in the ability to learn by experience, a process commonly referred to as "learning by doing" (Salvador 2004). This effect pertains to the fact that the workers are likely to improve their productive efficiency over time by "learning" from their experiences in their respective jobs. Such effect can be applied in the national R&D projects, so that the researchers in such projects can improve their skills and abilities even without attending training courses. The accumulated human capital may become a major source of technical change and productivity growth in the nation.
The focus of this paper is the measurement of the economic effect of the national R&D program from the compare the human-capital rates of return by manufacturing groups. The human-capital accumulation model developed by Mincer (1974) was adopted in terms of the rate of the researchers' investment in human capital. The estimation of the earning function is an importance process for the human-capital accumulation model. An early research (Mincer and Polachek 1974), estimated the earning function, particularly the effects of intermittency on wages, using OLS (Ordinary Least Squares estimator). Many, however, have questioned the strength of these results because statistical problems (e.g., heterogeneity, endogeneity, and selectivity) may affect the validity of their specifications (Kim 1994).
An important advantage of the pooling time series and cross-sectional data is that they have the ability to control individual-specific effects that are possibly unobservable, which may be correlated with the other variables included in the specifications of an economic relationship. The analysis of cross-sectional data alone, however, can neither identify nor control such individual effects (Hausman and Taylor 1981). Many researches tried to use panel data to estimate the earning function. Especially, the Hausman-Taylor estimation method has the advantage of being able to

control the correlation between the regressors and the unobserved individual effects, and to identify the estimates of the time-invariant variables.
In this research, the earning function was estimated, and the results were compared using various panel estimation methods (OLS, fixed-effect, and Hausman-Taylor). Based on the results of such earning function estimation, the human-capital accumulation that led to learning by undertaking an R&D project by industry was calculated.

Human capital accumulation model and earning function

The Human capital accumulation model

In this study, modified human-capital accumulation model based on Mincer (1974) was adopted. This model calculates the human capital based on the earning function related to an individual's education level and experience period. It can accurately measure the human capital as evaluated in the market.
Earning capacity" ( ) was defined as the potential earnings resulting from one's use of his or her whole labor time to work.

$$E_t = \gamma p K_t = E_{t-1} + \gamma C_{gt-1} - \delta_{t-1} E_{t-1}$$

where is the human-capital return rate, the unit price of human capital, a private human-capital stock, and is the expenditure on the net human-capital investment at any time period . At any time, the observed earnings equal the potential earnings minus the total investment. Thus:

$$C_{gt} = C_{nt} + \delta p K_t$$

$$W_t = E_t - C_{gt}$$

Following the investment theory, the potential earnings in the next year will be augmented by the returns on the initial investment. In general,

$$E_1 = E_0 + \gamma C_{n0}$$

$$E_2 = E_1 + \gamma C_{n1} = E_1 + \gamma C_{n0} + \gamma C_{n1}$$

$$E_t = E_0 + \gamma \sum_{i=0}^{t-1} C\_ni$$

Polachek and Siebert (1993) pointed out that is difficult to observe dollar investments, and that direct data on either direct or individual investments are readily available. For this reason, Mincer (1974) assumed that a measure of the time involved is relied on only by investment. represents the proportion of one's time spent investing, or the time-equivalent investment, expressed as:

$$s_t = \frac{C_{nt}}{E_t}$$

Substituting for yields and taking the logarithms of both sides yields:

$$lnE_t = lnE_0 + \sum_{i=0}^{t-1} ln\,(1 + \gamma s_i)$$

The term , representing the time-equivalent investment, can be divided into two segments: the full-time schooling period and the post-schooling period. When represents years of schooling, is the rate of return to schooling, and is the rate of return to post-schooling.

$$lnE_t = lnE_0 + \gamma_s \sum_{i=0}^{s} s_i + \gamma_p \sum_{i=S+1}^{t-1} s_i$$

During the schooling phase, since , implying that:

$$lnE_t = lnE_0 + \gamma_s S + \gamma_p \sum_{j=1}^{t-1} s_i$$

Polachek and Siebert (1993) assumed that human capital will be a monotonically declining function of age. This means that the human-capital stock that is accumulated diminishes within a 25-year period. The application of the following equation to the above equation will be expressed as:

$$lnE_t = lnE_0 + \gamma_s S + \gamma_p \alpha t - \frac{\gamma_p \alpha}{50} t^2$$

Since earning capacity is unobservable, it must be substituted by observable earning. The earning function is thus:

$$lnW_t = \left(lnE_0 - \frac{\delta}{\gamma_p} - \alpha\right) + \gamma_s S + \left(\gamma_p \alpha + \frac{\alpha}{25}\right) t - \frac{\gamma_p \alpha}{50} t^2$$

In this study, we added four more variables in earning function to represent individual and company characteristics. Finally, the earning function used in estimation was consisted of constant, education period, experience, experience squared, the interaction (multiplication) between education and experience, gender dummy, company size dummy, union dummy, and marriage dummy.

$$lnE_{t,i} = \alpha + \beta_1 S_{t,i} + \beta_2 t_{t,i} + \beta_3 t_{t,1}{}^2 + \beta_4 S_{t,i} \cdot T_{t,i} + \beta_5 D_{sex_i}$$

$$+\beta_{6\sim10} D_{size2\sim6_{t,i}} + \beta_{11} D_{union_{t,i}} + \beta_{12} D_{marriage_{t,i}}$$

After the estimation of the earning function, the human-capital accumulation should be calculated as:

$$lnC_{nt} = ln\alpha\left(1 - \frac{t}{25}\right) + lnW_t + \alpha\left(1 - \frac{t}{25}\right) + \frac{\delta}{\gamma_p}$$

The panel data earning function specifications

In this study, the earning function approach suggested by Mincer (1974) was modified to account for the panel data. An important advantage of using panel data is that they have the ability to control individual-specific effects that are possibly unobservable, which may be correlated with the other variables included in the specifications of an economic relationship (Hausman and Taylor 1981). Let

where and is an individual time-invariant regressor, whereas is time-variant and is assumed to be and , both independent of each other and among themselves.

The above estimation of the earning function using the OLS estimator is not problem-free. The presence of measurement errors and unobserved variables, such as ability and motivation, may be correlated with schooling (Mainar 2005). Specifically, it has been shown that the measurement error bias pulls the OLS estimates downward (Card 2001). When conducting panel analysis, it is possible to control the endogeneity caused by the individual effect. The within-group fixed-effect and Hausman-Taylor estimation methods are thus often used.

The within-group fixed-effect estimation method weeps out the latent unobservable variable ( ) from earning function by transforming each observation with a first difference or mean-deviation operator (Kim 1994). This means that the fixed-effect estimator is obtained by subtracting each individual's mean variable value for each time period observation, as indicated in the following equation:

$$ln(W_{it} - W_i) = (X'_{it} - X_i)\beta + v_{it} - v_i$$

As a result, the fixed-effect estimation method considers the individual effect with regard to the endogeneity of the variables. The time-invariant variables (gender as well as other socioeconomic-background variables that do not vary over time), however, may also be correlated with , which is correlated with the time-variant variables . In this case, the fixed-effect estimation method sweeps out as well as from the equation.

Hausman and Taylor (1981) suggested an alternative procedure. This procedure allows the simultaneous control of the correlation between the regressors and the unobserved individual effects, the identification of the estimates of the time-invariant covariates (e.g., education), and the avoidance of the insecurity associated with the choice of suitable instruments since the individual means over time of all the included regressors can serve as valid instruments (Mainar 2005). The matrices can be divided into two sets of variables: and . and are assumed to be exogenous and not correlated with and , while and are assumed to be endogenous due to their correlation with , but not with . Hausman and Taylor (1981) suggested an instrumental variable estimator that premultiplies above equation by , where is the variance-covariance term of the error component , and then performs 2SLS using the instruments. is the within-transformation matrix with , and is the individual mean (Mainar 2005). As a result, the Hausman-Taylor estimation method is more efficient than the fixed-effect estimation method.

The data

The dataset used in this study was obtained from the Korean Labor & Income Panel Study (KLIPS) for the period 2001-2006. The survey is conducted annually to track the characteristics of households as well as the economic activities, income, education, job training, and social activities of individuals from 1998 to 2008. The dataset has the strength of keeping about 76% of its respondents. These researchers' sample consists of 5,748 randomly chosen prime-age wage laborers aged 20-60 years. The period 2001-2006 was chosen considering sample consistency.

To determine the effects of the national R&D projects, total industry and three categories of the manufacturing industry were considered: the light, heavy-chemicals, and high-tech industries. It was assumed that the effects of the national R&D projects are felt by such industries. The effects of the national R&D projects can be identified by analyzing the human-capital accumulation in each of such groups.

The key characteristics of the aforementioned groups are summarized in Table 1. The average education level (12.64 years) in the total industry is higher than that in the other manufacturing groups. Among the three groups, the education level in the group 3 was found to be higher than that in the groups. Some differences are also shown in the average wage per month in the three manufacturing groups. In the group 3, the average wage per month is higher than 40 million compared to the group 1, which have the smallest average wage per month. The gaps may lead to differences in the human-capital accumulation effect by manufacturing group.

Table1: The relevant mean values of variables

	Total industry	**Manufacturing group 1**	**Manufacturing group 2**	**Manufacturing group 3**
Age (year)	37.77	39.24	38.64	36.35
Education (year)	12.94	11.62	12.28	12.79
Experience (year)	17.81	20.62	19.36	16.55
Wage for month (million won)	162.99	134.47	170.76	174.45
Number of individuals	3612	392	247	566
Number of observations	5748	549	458	1027

Results

In this section, two sets of results are presented: one obtained by estimating the earning function and the other by analyzing the human-capital accumulation by manufacturing group.

Estimates of the earning function

Table 3 shows the results of the estimations that were used for the study samples. The first column for each manufacturing group shows the OLS estimates, the second column the fixed-effect estimates, and the last column the Hausman-Taylor estimates. The exogenous time-variant variables, 0 , are experience squared, the interaction(multiplication) between education and experience , company size dummy, union, and marriage. The endogenous time-variant variables, 0 , are education and experience. The exogenous time-invariant variable 0 is gender.

It can be observed that the Hausman-Taylor estimation coefficients are higher than the OLS estimation coefficients in absolute values for most of the important variables, such as education and experience. This proves that the result of Card (2001), which pertains to the OLS estimates, underestimated the coefficient. Focusing on the education level, the education coefficient estimated by the Hausman-Taylor model rose to 0.136, which is 36% larger than the OLS estimate and 16% above the fixed-effect estimate in the total industry. In the manufacturing group 3, the Hausman-Taylor estimation coefficient was 300% above the OLS estimate. This shows that if the individual effects that are correlated to the other variables will not be controlled, the coefficient can be underestimated.

It was found that the rate of return to education is higher in the group 2 than in the two other manufacturing groups. The earnings from education for the group 2 are 234% above those in the total industry, 334% above those in the group 1, and 86% above those in the group 3.

The rate of return to experience is also higher in the group 2 in the two other manufacturing groups that were considered in this study. The earnings from a year's improvement in experience in the group 3 are 222% above those in the total industry, 256% above those in the group 1, and 22% above those in the group 3. These results imply that the learning-by-doing impact from participation in an R&D project is highest in the group 2 due to education and experience have the largest rate of return or earning effect in the manufacturing groups.

The other coefficients show acceptable results. Experience2 has a negative coefficient that reflects a concave relationship between earning function and experience. Males were also shown to have higher wages compared to women. The marriage coefficient showed different results in the two estimation methods that were used. The OLS results showed that marriage has a negative effect on wage. The Hausman-Taylor model, on the other hand, showed positive results for marriage. It is widely accepted that marriage has a positive effect on wages. Such result is another reason that the OLS estimation of earning function is said to have a bias. In the fixed-effect model, the time-invariant variable (gender) is omitted by the mean deviant equation.

Human capital accumulation

The accumulation of human capital was analyzed in this study using the model suggested by Mincer (1971), which was reviewed in the previous section. To accurately calculate the learning-by-doing effect, the total average wage and the participation rate must be known by the researchers who are participating in a certain R&D project. The purpose of this research, however, was not to evaluate a specific national R&D projects but to compare the human-capital rates of return by manufacturing group. For this reason, it was assumed that each of the manufacturing groups considered in this study has an R&D project with 100 researchers who have the same wages and experience periods with total industry in Table 1. The human-capital accumulation (HCA) results for each manufacturing group are summarized in Table 3, reflecting the important variables in the human-capital accumulation model. In manufacturing group 2, the human-capital accumulation level was highest among the other groups.

Table2: Estimation results of earnings function by industry

(1) standard errors in parantheses; (2) ***, **, * are represent 1, 5, and 10% significance level, respectively; (3) a Reported fraction of variance due to u_i,; (4)b Specification test with null hypothesis of

_	Total industry			Manufacturing group 1			Manufacturing group 2			Manufacturing group 3		
_	OLS	F-E	H-T	OLS	F-E	H-T	OLS	F-E	H-T	OLS	F-E	H-T
Education	0.1009*** (0.0053)	0.1167*** (0.0192)	0.1361*** (0.0141)	0.0926*** (0.0147)	0.1343*** (0.0336)	0.1036*** (0.0214)	0.1115*** (0.0228)	0.2615** (0.1121)	0.4498*** (0.0789)	0.0849*** (0.0113)	0.1825*** (0.0496)	0.2423*** (0.0383)
Experience	0.0519*** (0.0051)	0.1616*** (0.0176)	0.0703*** (0.0114)	0.0491*** (0.0142)	0.2611*** (0.0585)	0.0637** (0.0258)	0.0643*** (0.0201)	0.3614*** (0.1029)	0.2269*** (0.0601)	0.0422*** (0.0110)	0.2570*** (0.0387)	0.1853*** (0.0284)
Expierience^2	-0.0008*** (0.0001)	-0.0011*** (0.0002)	-0.0099*** (0.0001)	-0.0006*** (0.0002)	-0.0012** (0.0006)	-0.0007** (0.0003)	-0.0010*** (0.0002)	0.2615*** (0.1121)	-0.0018*** (0.0006)	-0.0005*** (0.0001)	-0.0021*** (0.0003)	-0.0020*** (0.0003)
Education* Experience	-0.0010*** (0.0002)	-0.0009 (0.0010)	0.0016** (0.0006)	-0.0014** (0.0006)	-0.0070** (0.0032)	0.0033*** (0.0012)	-0.0010 (0.0009)	-0.0087 (0.0059)	-0.0044 (0.0032)	-0.0008 (0.0005)	-0.0044* (0.0023)	-0.0024** (0.0016)
Sex	0.3565*** (0.0125)	-	0.2871*** (0.0345)	0.4312*** (0.0353)	-	0.4775*** (0.1328)	0.3807*** (0.0583)	-	0.2706 (0.2214)	0.4789*** (0.0302)	-	0.4384** (0.1154)
Marriage	-0.1353*** (0.0159)	-0.0034 (0.0314)	0.0518** (0.2124)	-0.0969** (0.0475)	0.0919 (0.1017)	0.2134*** (0.0621)	-0.1212** (0.0604)	0.0176 (0.1187)	0.1518* (0.0869)	-0.1287*** (0.0349)	-0.0218 (0.0585)	0.0731** (0.0449)
Union	0.0545*** (0.0131)	0.0522*** (0.0136)	0.1551 (0.0100)	0.0273* (0.0407)	0.0045 (0.0366)	-0.0273 (0.0237)	0.0370 (0.0473)	0.0773* (0.0458)	0.0760** (0.0360)	0.0516* (0.0275)	0.1025 (0.0264)	0.0661*** (0.0210)
10≤Company size<30	0.1232*** (0.0223)	0.0550 (0.0483)	0.0929*** (0.0298)	0.0548 (0.0544)	0.1540 (0.2039)	0.2203** (0.1042)	0.0725 (0.0988)	0.0069 (0.2016)	-0.0113 (0.1446)	0.0469 (0.0748)	0.1681 (0.1818)	-0.2329* (0.1566)
30≤Company size<70	0.1255*** (0.0226)	0.0944** (0.0440)	0.1237*** (0.0276)	0.1086* (0.0572)	0.1911 (0.1692)	0.2187** (0.0876)	0.1333 (0.0906)	-0.0788 (0.1954)	-0.0684 (0.1393)	0.0697 (0.0741)	0.2252** (0.1118)	0.1419 (0.0750)
70≤Company size<300	0.1254*** (0.0213)	0.1507*** (0.0416)	0.1634*** (0.0258)	0.1054* (0.0540)	0.3514* (0.1887)	0.2803*** (0.0964)	0.2413*** (0.0884)	0.1706 (0.2008)	0.0794 (0.1393)	0.0825 (0.0678)	0.1474** (0.0975)	0.1622* (0.0677)
300≤Company size<1000	0.2746*** (0.0219)	0.1695*** (0.0424)	0.1858*** (0.0265)	0.2532*** (0.0650)	0.4366** (0.1919)	0.3664*** (0.0989)	0.2813*** (0.0905)	0.1394 (0.2036)	0.1085 (0.1438)	0.2241*** (0.0702)	0.3100*** (0.0987)	0.2249*** (0.0675)
1000≤Company size	0.3968*** (0.0186))	0.1790*** (0.0412)	0.2233*** (0.0255)	0.3322*** (0.0565)	0.3743** (0.1880)	0.3471*** (0.0964)	0.4408*** (0.0856)	0.1931 (0.2049)	0.1883 (0.1438)	0.4317*** (0.0661)	0.1464** (0.0970)	0.1910** (0.0682)
constant	2.9641*** (0.0875)	1.2737*** (0.3032)	1.8074*** (0.2181)	3.1028*** (0.2501)	0.0363 (0.6114)	1.4769*** (0.3693)	2.6848*** (0.3734)	-1.9589 (1.6225)	-3.4153 (1.2123)	3.1275*** (0.1842)	0.0187 (0.7309)	-0.2870*** (0.5623)
R^2	0.4716	0.4055		0.5273	0.5903		0.4613	0.5138		0.5347	0.5538	
RHO[a]			0.97			0.99			0.98			0.98
Test[b]			χ^2=179			χ^2=372			χ^2 =272			χ^2 =672

correlation between the instrument and α_i ; (5) F-E and H-T are result of fixed-effect estimation and Hausman-Taylor estimation respectively.

Table3: Human capital accumulation

Estimation method	coefficient	Total industry	Manufacturing group 1	Manufacturing group 2	Manufacturing group 3
OLS	α	0.3210	0.4207	38,844	0.4002
	γ_p	0.1217	0.0768	0.1197	0.0654
	δ	0.0737	0.288	0.0717	0.0174
	HCA(million won/year)	**36,260**	**38,844**	**46,239**	**32,929**
Fixed-Effect	α	2.6696	4.9917	5.5899	3.8406
	γ_p	0.0205	0.0123	0.0247	0.0269
	δ	-0.0275	-0.0357	-0.0233	-0.0211
	HCA(million won/year)	**84,789**	**64,826**	**608,180**	**297,313**
Hausman-Taylor	α	0.5215	0.6807	3.3745	2.1391
	γ_p	0.0947	0.0536	0.0272	0.0466
	δ	0.0467	0.0056	-0.0208	-0.0014
	HCA(million won/year)	**55,774**	**51,677**	**233,547**	**216,001**

Conclusion

On the concept of learning by doing, the results of this study imply that the national R&D program has been successful in terms of providing the researchers with opportunities to accumulate human capital. Based on these results, four conclusions can be drawn.

First, the human-capital accumulation level of manufacturing group 2, which is consisted of the heavy industries, was highest among the three manufacturing groups and the total-industry average. This was predictable because manufacturing group 2 was estimated to have the highest education and experience effect on earning functions.

Second, the fixed-effect model was inclined to overestimate the effect of learning by doing (career). This is because such model cannot consider the time-invariant individual variables, such as gender.

Third, the human-capital accumulation estimates by the Hausman-Taylor model were bigger than those by the OLS model. The Hausman-Taylor model can control unobserved individual variables that the OLS model cannot control. For this reason, the effect of learning by doing (career) was more exactly identified by the Hausman-Taylor model than by the two other models.

Fourth, in the results of the estimation of the wage function, the effect of education and career in manufacturing group 2 was highest, higher than that in manufacturing group 3 and manufacturing group 1, in that order. In general, the bigger the company size is, the higher the wage level. This was not true, however, in manufacturing groups 1 and 3 in this study. The middle size (over 300 and under 1,000) was the highest.

References

01. Card, D. (2001). "Estimating the return to schooling: Progress on some persistent econometric problems." Econometrica, Vol. 69, No. 5, pp. 1127-1160.

02. Garcia-Mainar, I. & V. M. Montuenga-Gomez (2005). "Education returns of wage earners and self-employed workers: Portugal vs. Spain." Economics of Education Review, Vol. 24, No. 2, pp. 161-170.

03. Hausman, J. A. & W. E. Taylor (1981). "Panel Data and Unobservable Individual Effects." Econometrica, Vol. 49, No. 6, pp. 1377-1398.

04. Heo, E., Y. Lee, & J. Kim. (2008) "Evaluation of the Human Resource Development Effect on Hydrate R&D Project in Korea Using Human Capital Accumulation Model," Journal of the Korean Society for Geosystem Engineering, Vol. 45, No. 5, pp. 516-525.

05. Kim, M. K. & S. W. Polachek (1994). "Panel estimations of male-female earning functions," The Journal of Hu-

man Resources, Vol. 29, No. 2, pp. 406-428.
06. Mincer, J. (1974). “Schooling, Experience and Earnings,” National Bureau of Economic Research, New York.
07. Polachek, S. W. & W. S. Siebert. (1993) “The economics of earnings, Cambridge University Press,” Cambridge.

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