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TECHNOLOGICAL CHANGE AND EDUCATIONAL WAGE DIFFERENTIALS IN KOREA

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ABSTRACT

This paper examines the effect of technological change on educational wage differential across industries in Korea during the 1980s. We assume that workers with a higher schooling level have higher learning efficiency than workers with a lower schooling level, and this difference in learning efficiency is assumed to increase with more rapid changes in technology. Using total factor productivity growth rates and R&D expenditures to sales as proxies for technological change, we estimate an expanded Mincerian earnings function. We find that workers are paid more in industries where technology changes rapidly than in industries where technology changes slowly. Particularly, there is a tendency for female workers with a 4-years of college education to benefit more from technological change than do other female workers. We also find that there appears to be substantial R&D spillovers from advanced countries to Korea, particularly evident in the association between male wages and OECD R&D expenditures by Industry of Use.

KEY WORDS: Technological Change

I. Introduction

This paper analyzes the effect of technological changes on educational wage differentials across industries in Korea during the 1980s. Education enhances human abilities in several ways. The most obvious effect of formal schooling is the development of the vocational skills which are useful in the future labor market. At the same time, through general and liberal arts education, formal schooling can also increases the efficiency with which new skills are acquired in the labor market (Rosen 1977). This implies that highly educated workers have a comparative advantage with respect to learning and implementing new technologies. Therefore, returns to education can increase when technology changes rapidly.

Choi (1991) showed that the relative wage difference between college graduates and high school graduates in Korea is large from the early period of work experience, and that the relative difference increases until the end of the working life, while the relative wage difference between middle school graduates and primary school graduates is small.[1] The large differences in relative wages across education levels suggest that more educated workers accumulate more human capital on the job than less educated workers, assuming that both the supply of labor and the derived demands for labor with various skill levels remain constant. This suggests that formal schooling and "On-the-Job Training" in human capital production are complementary in Korea. If wage differentials across education levels are positively correlated with technology changes, then, in Korea, educational wage differentials would be larger in industries where

1. Post-school experience used in this paper is the potential experience (age-schooling-7), not the actual labor market experience.

technology changes rapidly.[2]

In this paper, using a modified Mincerian earnings function, we will test whether increases in the returns to education are associated with various measures of technological change. As a measure of technological change across industries, we use (1) total factor productivity growth rates in Korea, (2) research and development (R&D) expenditures in Korea and (3) such R&D expenditures in OECD countries.

The remainder of this paper is organized as follows. Section II briefly reviews the previous studies on the effect of technological changes on returns to education. Section III sets up the empirical specifications and describes the data used in the investigation. Section IV analyzes empirical results, and Section V concludes this paper.

II. Previous Studies

In explaining the phenomena that returns to education have not declined under the pressure of rapidly rising average educational levels, Welch (1970) found that the wage differentials between college graduates and high school graduates are closely related to changing technology.[3] Using the agricultural research expenditures (federal and state expenditures) as

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2. Technical level and educational wage differentials must be positively related. In this paper, however, we consider the relation between technical change, not technical level, and educational wage differential.

3. Welch (1970) decomposed the effects of education into two parts: a "worker effect" and an "allocative effect". Higher levels of education may simply permit a worker to accomplish more with the resources at hand. This "worker effect" is the marginal product of education or the increased output per unit of the worker's education, *holding other factor quantities constant*. In addition, higher levels of education may enhance a worker's ability to acquire and decode

a proxy for technological change, he estimated the agricultural production function in the U.S. in 1959. He found that the earnings differential between male college graduates and male high school graduates employed in rural farm sector would fall from 1.62 to 1.43 if the research expenditures per farm were to fall from \$28.40 to \$4.30, holding factor ratios constant. Many other studies have subsequently used data from developing countries to indicate the presence of the effect of education on allocative ability (Schultz 1975).

In addition to the evidence from agricultural production, other studies assess the effect of technological changes on returns to education in nonagriculture activities. Based on the hypothesis that highly educated workers have a comparative advantage with respect to the adjustment to and implementation of new technologies, Bartel and Lichtenberg (1987) showed that the relative demand for educated workers declines as the age of plant increases, especially in R&D-intensive industries. Based on the same hypothesis, Gill (1990) also cited a systematic, positive relationship between technical change and education level in U.S. industries. He used the sectoral growth rate in total factor productivity as a proxy for technical change.

Mincer (1989) emphasized the computer revolution in the U.S. which is likely to have raised the relative demand for more-educated and flexible workers and reduced the demand for

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information about costs and productive characteristics of other inputs. As such, a change in education results in a change in other inputs including the use of some "new" factors that otherwise would not be used. This is a so-called "entrepreneural capacity", which is, however, not restricted to entrepreneur and can be enhanced by education.

Schultz (1975) calls this an ability to deal with disequilibria. He suggested that people consciously reallocate resources in response to changes in economic conditions, and that "allocative ability" rests in the ability to reallocate, and not only for entrepreneurs. Housewives also devote their time in combination with purchased goods and services in household production. Students likewise reallocate their own time along with the educational services they purchase as they respond to changes in expected earnings along with changes in the value of the personal satisfaction they expect to derive from their education (1975, p. 827).

physical labor. By using CPS (Current Population Survey) data in the U.S. from 1963 to 1987, Mincer (1991) showed that the year-to-year educational wage differentials are closely related to R&D expenditure per worker, which was used as a proxy for technological change. He also found that both Jorgenson type multifactor productivity growth indexes and net growth of goods imports are significant as alternatives, but that they have weaker explanatory power than R&D expenditures.

Lichtenberg (1991) extended previous research on the effect of investment in R&D on labor productivity at the country level. According to his findings, privately-funded R&D investment has a significant positive effect on productivity and this effect is quite large. He maintained that this finding does not support the hypothesis that there are complete, or at least instantaneous, international R&D spillovers.

III. Model Specification and Data

1. Model Specification

In this section, we will set up the empirical specification of earnings equation and the hypothesis to be tested, and explain the data to be used. The wage equation used in this study is specified as follows:

$$\ln W_i = \beta_0 + \beta_1 EDU_i + \beta_2 EXP_i + \beta_3 EXP_i^2 + \beta_4 D_i + \beta_5 EDU_i \cdot D_i + \gamma Z + u_i, \tag{9}$$

where $\ln W_i$ is the natural logarithm of the hourly wage rate of an individual worker *i*. EDU_i is years of schooling completed and EXP_i represents the post-school experience of the worker. Since the actual experience in the labor market is not observable, potential experience (age-Edu-

7) is used in this study. Workers are assumed to be observationally identical except for their schooling level, age and post-school experience. Z represents other factors affecting wages such as regional dummies and firm size dummies. Also, u_i is an error term with mean zero and variance σ^2 (i.e. $E(u_i) = 0$, $E(u_i u_i) = \sigma^2$), statistically independent of explanatory variables. D represents the degree of technical changes or degree of changing environments across industries. As a proxy for technical changes (=D), two different variables are used in this study: total factor productivity (TFP) growth rates and expenditures on research and development (R&D) as a share of sales across industries.[4]

Total factor productivity (A_t) is defined as the ratio of real output (Y_t) to a weighted average of the labor and capital inputs (X_t), while the weights are both labor's and capital's share of outputs, i.e.,

$$A_t = Y_t / X_t.$$

The proportionate rate of growth of total factor productivity ($\dot{A}_t$) is, then,

$$\dot{A}_t = \dot{Y}_t - \dot{X}_t.$$

Now, let's look at the suitability of total factor productivity (TFP) growth rate as a measure of technical change. TFP, Solow's (1957) measure of technological change, assumes that the economy is operating in the range of constant returns to scale. Non-constant returns to scale are embedded in the residual term. Therefore, the TFP growth rate consists of both a pure technical change component and a non-constant returns to scale component.

Another measure used in this study as a proxy for technical change is R&D expenditures

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4. "TFP" is an output measure of technological change while "R&D" is an input measure of technological change.

across industries. If technology is easily transferable, and freely accessible across countries, then R&D expenditure data from advanced countries may be a better proxy for technical change than the data from Korea.[5] We use both R&D data from Korea and from five OECD countries (namely, the United States, Japan, West Germany, France, and the United Kingdom) in alternative wage regressions.

We also need to distinguish R&D expenditures by Industry of Manufacture (IOM) and by Industry of Use (IOU), because a large proportion of R&D expenditures are spent in industries other than where they originated.[6] For example, an improvement in personal computers may be developed by a computer firm but then embodied in the computer and sold to a financial services firm. Moreover, R&D expenditures by IOU in advanced countries may be a better proxy than R&D expenditure by IOM for technological change in developing countries like Korea, where adaptation and modification of the invention is more important than pure invention to produce marketable goods. This proposition is consistent with the patterns of patents and utility models data[7], another measure of technological change.[8] Evenson (1990)

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5. Korea and Brazil purchase ninety-seven percent of their imported technology from industrialized countries, while the other Latin American countries purchase a significant amount of technology from semi-industrialized and developing countries (Evenson 1990).

6. The correlation coefficient between "R&D by IOM in OECD countries" and "R&D by IOU in OECD countries" is only 0.226 while the correlation coefficient between "R&D by IOM in Korea" and "R&D by IOM in OECD countries" is 0.933.

7. Utility models are a weaker form of protection for inventions provided by some countries such as Korea and Brazil. The qualifying standards are lower in two respects. First, novelty (i.e., new or not known before) is often, in practice, determined against national or regional standards rather than global standards. More importantly, the inventive step (i.e., not-obvious to one practicing the art) requirement is given a weaker interpretation. The utility model is thus generally regarded as a "petty patent" (Evenson 1988).

showed that the proportion exported to invention-using but not producing industries tended to decline with economic development especially for foreign origin R&D.

In the case of OECD countries, we get R&D expenditures by both IOM and IOU, based on the "Yale-Canada Patent Concordance" (Evenson, Putnam, and Kortum 1990),[9] and estimate separate regressions.[10]

The hypothesis tested in this study considers two factors: whether wages are higher in industries where technology changes are occurring faster and whether the relative wage differentials across educational levels are larger when technology changes more rapidly. The coefficient of the interaction term between education and D (=the rate of technological change) captures the effect of technology changes on educational logarithmic wage differential. Workers

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8. R&D expenditures are inputs in the production of economically valuable technological knowledge while patents are the outcome of the increase in economically valuable technological knowledge (Pakes and Griliches 1984).

9. The Yale Technology Concordance (YTC) was constructed using data from 183,288 patents granted in Canada between 1978-1987 (see Evenson, Putnam, and Kortum 1990). When a patent is granted in Canada, the patent examiners are required to assign an International Patent Classification (IPC) code to the patent and one or more industries of manufacturing and industries of use for the invention. By counting the number of occurrences of various IPC-industry combinations, it is possible to construct empirical probabilities for the probability of a patent in IPC i manufactured in industry j and used in industry k. We assume that the probability of mapping patents with given IPC codes into industries of manufacture and industry of use is the same as the probability of mapping R&D expenditures with given IPC codes into industries of manufacture and industry of use. It is these probabilities that were used in this dissertation to map R&D expenditure with given IPC codes into industries of manufacture and industry of use for the construction of R&D expenditures. Using the empirical probabilities in place of the true, unobserved probabilities also introduces some error; however, given the enormous number of patents used to make the concordance, the empirical probabilities should be close to their true values.

10. In the case of Korea, we cannot calculate "R&D expenditure by IOU" using the probability table from the "Yale-Canada Patent Concordance", because the industry classification codes for Korean data do not exactly correspond to those for OECD countries' data.

with a higher schooling level have higher learning efficiency than workers with a lower schooling level, and this difference in learning efficiency is assumed to increase as technology changes more rapidly. Therefore, the coefficient of the interaction term between education and D is hypothesized to be greater than zero (i.e., $\beta_5 > 0$). The effect of technology change on wages ($\partial \ln w / \partial D$) is also hypothesized to be greater than zero (i.e., $\beta_4 + \beta_5 EDU > 0$).

2. Data

The wage data used in this study are from the Korean Occupational Wage Survey (OWS) for 1982 and 1988. The survey is conducted by the Ministry of Labor in Korea, and each survey contains information on workers including sex, age, level of education, region, industry, number of hours worked in a month[11], regular monthly payments, overtime payments, yearly bonuses, and other variables.

The surveys cover over three-thousand establishments, selected by a stratified random sampling method from all establishments which employ 10 or more regular employees[12], except those in agriculture, forestry, hunting and fishing. They exclude government, local administrative and public educational agencies, as well as the army and police.

The total number of persons employed in the nonagricultural sector in 1981 was 9,242,000 (Source: Annual Report on Economically Active Population). Excluding the self-employed, family workers, and temporary workers, the remaining regular employees numbered

11. The reference period is March in each year.

12. As defined, "Regular employees" refers to those people whose labor contracts do not specify the hiring period or which specify a hiring period of one month or more. The definition includes temporary workers who had been employed more than 45 days before the survey date.

6,603,000 (Source: Establishment Census Data). From this same source, excluding the public sector workers, the number of regular employees was 4,973,000. About 82% of regular employees were in establishments with 10 or more employees (Source: Establishment Census Data). Therefore, the survey represents about one-half of the labor force in nonagricultural sectors.[13]

The data used in this paper consist of a 10% random sample of workers drawn from the 1982 OWS and 20% from the 1988 OWS. Workers between 15 and 65 years of age have been included in the random samples.[14]

Total factor productivity growth rates are from Yeon (1979), who estimated TFP growth rates across 25 industrial sectors in Korea from 1962 to 1976 (see Table 1).

R&D expenditure data in Korea (IOM) are based on *Major Indicators of Industrial Technology* surveyed by the Korean Industrial Research Institute (1990). The latter surveyed establishments with 100 or more employees and those with less than 100 employees which have research institutes and/or which spend research funds for the development of technology. Table 2 shows the total R&D expenditures across industries from 1982 to 1988, and the average ratio of R&D expenditures as a percentage of sales (=R&D intensity) from 1982 to 1988. The relation between R&D intensity and education level seems to be positive. Table 3 shows that,

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13. Notably, the wage distribution of workers excluded from OWS does not appear to be the same as that of workers in OWS because there exist substantial wage differences across different establishment sizes and different industries. To see the wage distribution of the whole economically active population, it is necessary to analyze individual excluded workers groups (self-employed, family workers, part-time workers, workers in the public sectors and workers in small establishments) separately. Choi (1993) analyzed the effect of the establishment size on wage distribution in Korea during the 1980s.

14. The retirement age of wage earners in Korea is less than or equal to 65.

in the case of males, the proportion of workers with less than 10 years of schooling is 36.1% of the total workers in industries where R&D intensity is less than 1, while it is only 24.5% in industries where R&D intensity is greater than 1 in 1988. In the case of females, this proportion is 67.6% in industries where R&D intensity is less than 1, while it is only 31.1% in industries where R&D intensity is greater than 1. Similar patterns are found for the year 1982.

R&D expenditures data in five OECD countries (U.S., Japan, West Germany, France, and United Kingdom) are from OECD's *Basic Science and Technology Statistics* (1990). We distinguish R&D expenditures by industry of manufacture (IOM) and by industry of use (IOU) based on the "Yale-Canada Patent Concordance." We divide R&D expenditure by output in each industry and calculate the average ratio of R&D to output across five countries from 1978 to 1987.[15] Table 4 shows the average ratio of R&D to output in the five OECD countries by industry of manufacture and by industry of use.

IV. Empirical Results

The rate of total factor productivity growth is used as a proxy for the output of technology change, and it is added to the earnings equation (Equation (9)) estimated by the least square method. Table 5 shows that the coefficients of the "Total Factor Productivity" variable

15. The value of output in each industry is comprised of: (a) the value of all products of the establishment; (b) the net change between the beginning and the end of the reference period in the value of work in progress and stocks of goods to be shipped in the same condition as received; (c) the value of industrial work done or industrial services rendered to others; (d) the value of goods shipped in the same condition as received less the amount paid for these goods; and (e) the value of fixed assets produced during the period by the unit for its own use (U.N., *Industrial Statistics Yearbook*, 1991).

in both males and females are positive and significant. This means that workers are paid higher wages in industries with higher total factor productivity growth rates than in industries with lower total factor productivity growth rates. The magnitude of the coefficient is much larger in the case of females (=0.057 in specification (I)) than males (=0.006). This implies that the wage gap between genders is smaller in industries where technology changes more rapidly. The coefficients of the interaction terms between "total factor productivity" and "education (=years of schooling)" for both males and females are also significant and positive as hypothesized. This suggests that wage differentials associated with total factor productivity growth rates increase as education level increases. However, male workers with lower education levels are not paid more in industries where technology changes rapidly because the coefficient of the "TFP" variable in specification (II) is negative (= −0.071). Only workers with at least a high school education are paid more in industries where technology changes more rapidly. When we introduce the "education dummy variables" instead of "years of schooling" in the interaction terms in specification (IV), the coefficients of interaction terms are positive and significant, but the magnitude of each coefficient does not always increase as education level increases. The coefficient of the interaction term between "TFP" variable and "high school dummy" is larger (=0.047) than the coefficients of interaction terms between "TFP" variable and "college dummies" (=0.022 for 2-year and 0.044 for 4-year). In the case of females, workers are paid more in industries with higher total factor productivity growth rates than in industries with lower total factor productivity growth rates.[16] The coefficient of the interaction term between "TFP"

16. In specification (II), the coefficient of "TFP" variable is negative (=-0.078), but the coefficient of interaction term is positive (=0.015). Therefore, workers with at least 6 years of education (= primary school education) can reap the benefits of technological change.

and "education dummy" is positive and significant, but the magnitude of the coefficient does not increase as education level increases.

The "TFP" growth rates, however, are estimated from 1962 to 1976 and the wage data used in this estimation are from the 1982 OWS. This time difference may cause another bias. Unfortunately, estimates of "TFP" in recent periods are not available at this time.

As a proxy for the inputs to technological change, R&D expenditures are used in our estimation. First, we use R&D expenditures across industries in Korea. Table 6 shows the OLS estimates of earnings equation with R&D expenditures as a percentage of sales. The R&D intensity data is for the period between 1982 and 1988 and the wage data used here are from the 1988 OWS. Therefore, the results from Table 5 and from Tables 6, 7 and 8 are not directly comparable.[17]

As expected, the coefficients of the "R&D intensity" input variable are positive for both male and female wages. Roughly speaking, a 1 percent increase in the ratio of R&D to sales leads to a 0.8 percent increase in average wage for males and 1.3 percent increase for females. The coefficient of the interaction term between the "R&D intensity" and "Education" is also positive in the case of males (=0.007 in specification (II) in Table 6). However, when we consider the "education dummy variables" instead of "years of schooling" in the interaction terms in specification (IV), the coefficient of the interaction term is positive for high school graduates, but the coefficients of the other interaction terms are insignificant or negative. This

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17. In the Appendix Tables of this essay, we report the results of OLS estimates of earnings equation with "TFP" variables using the 1988 wage data and the estimates of earnings equation with "R&D intensity" variables using the 1982 wage data (Tables A.1 to A.4). These results are not much different from the results reported in Tables 5 to 8.

implies that the average wage of workers in industries where technology changes more rapidly is higher than that of workers in industries where technology changes more slowly, but the educational wage differential associated with technological change does not always increase with the level of education. In the case of females, the interaction term between "R&D intensity" and "years of schooling" in specification (II) is negative (=-0.002), but the interaction term between "R&D intensity" and "4-year college dummy" in specification (IV) is significantly positive (=0.046). This implies that a 1 percent increase in the ratio of R&D to sales leads to a 1.8 percent (=0.018 in specification (III)) increase in average wage of female workers, but leads to a 6.9 percent (=0.023+0.046 in specification (IV)) increase in the wage of 4-year female college graduates.[18]

As mentioned above, if technology is easily transferable and freely accessible across countries, then the R&D expenditures in larger and more advanced countries may be a better proxy for global changes in technology. First, we use the ratio of R&D to output by Industry of Manufacture (IOM). Table 7 shows that the coefficients of "R&D" variable (R&D intensity in OECD countries) are significant and positive for both males and females. These estimates imply that a 1 percent increase in the ratio of R&D to output in the advanced countries leads to an approximate 1.8 percent increase in average wages for Korean male workers in that industry and 0.7 to 1.0 percent increase for female workers. In the case of males, the coefficient of the interaction term between "R&D intensity in OECD countries" and "education" is also positive in specification (II) (=0.001), but specification (IV) shows that the coefficient of the interaction

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18. The proportion of female college graduates in industries where R&D intensity is high among the total female college graduates does not change very much from 1982 to 1988 (see Table 3).

term between "R&D intensity" and "education dummies" are negative. In the case of females, the coefficient of the interaction term between "R&D intensity in OECD countries" and "education" is negative in specification (II) (=-0.001), and the coefficient of the interaction term between "R&D intensity" and "education dummies" are insignificant in specification (IV). Therefore, the hypothesis that educational wage differential associated with technological change increases with the level of education is not strongly supported by the OECD (IOM) data.

When we use the ratio of R&D to output in advanced countries by Industry of Use (IOU), the magnitude of the coefficient on the "R&D intensity" variable is larger than when we use the "R&D intensity" by IOM (see Table 8). Moreover, in the case of male, the "R&D intensity" by IOU explains more of the variance of the Korean male workers' wages than does the "R&D intensity" by IOM (i.e., R^2 is higher in IOU case than in IOM case). This is consistent with the hypothesis that R&D expenditures in advanced countries by IOU is a better proxy than R&D expenditures by IOM for technological change in less developed countries, where adaptation and modification of the invention is more important than pure invention to produce marketable goods.

In the case of males, the coefficient of the interaction term between "R&D intensity in OECD countries" and "education" is negative in both specification (II) and (IV). In the case of females, however, the coefficient of the interaction term between "R&D intensity" and "education" are positive in both specification (II) and (IV). Moreover, the magnitude of the coefficient of the interaction term in specification (IV) increases with the level of education. Particularly, the magnitude of the coefficient of interaction between "R&D intensity" and "4-year college dummy" is as large as 0.193.

In sum, technological change increases the average wage of workers for both males and females, but the hypothesis that educational wage differential associated with technological change increases with the level of education is not strongly supported by the Korean data for 1988. In the case of females, however, there is a tendency that 4-year college graduates benefit more from technological change than do other female workers.

V. Conclusion

We have examined the effect of technological change on educational wage differentials across industries in Korea during the 1980s. We assumed that workers with higher schooling levels have higher learning efficiency than workers with lower schooling levels, and this difference in learning efficiency was assumed to increase as technology changes more rapidly. Using total factor productivity growth rates and R&D intensities in both Korea and five OECD countries as a proxy for technology change, we estimated a modified Mincerian earnings function.

We found that workers are paid more in industries where technology changes rapidly than in industries where technology changes slowly. It is unclear whether the educational wage differential associated with technological change increases with the level of education. However, there is a tendency for female workers with a 4-years of college education to benefit more from technological change than do other female workers.

We also found that there appears to be substantial R&D spillovers from advanced countries to Korea, particularly evident in the association between male wages and OECD R&D

expenditures by Industry of Use. This suggests that adaptation of new technology may require better educated male workers.

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Table 1. Total Factor Productivity
across Industries in Korea: 1962-1976

Industries	Annual Average of TFP
Mining	0.2
Foods & Beverage	1.6
Textiles & Clothing	1.6
Leather Products	1.3
Wood & Furniture	0.9
Paper Products	3.4
Printing & Publishing	5.0
Chemicals	4.8
Petroleum & Coal Products	3.3
Rubber Products	4.4
Non-metallic Mineral	3.0
Basic Metal	4.9
Metal Products	5.5
Machinery	4.3
Electrical Machinery	2.9
Transportation Equipment	1.9
Miscellaneous Manufacturing	5.0
Electricity & Gas	5.2
Construction	2.4
Wholesale & Retail Trade	3.9
Transportation & Storage	4.8
Dwelling	7.2

Source: Yeon (1979).

Table 2. R&D Expenditures
across Industries in Korea: 1982-1988

Unit: Million Korean Won

Industries	Total R & D Expenditure*	Percentage of Sales (%)**
Mining	15,433	0.783
Food & Beverage	270,297	0.609
Textiles	235,943	0.731
Wood	6,754	0.499
Paper & Printing	57,841	0.833
Industrial Chemicals	157,844	0.891
Other Chemicals	389,627	1.791
Petroleum Refineries	70,691	0.194
Petroleum and Coal Products	21,341	0.530
Rubber Products	148,591	1.274
Plastics Products	43,592	1.593
Non- Metallic Mineral Products	108,039	0.802
Basic Metal Industries	187,067	0.403
Fabricated Metal Products	86,094	1.139
Machinery	497,098	1.828
Electrical, Electronic Machinery	2,096,069	3.148
Other Manufacturing	36,921	1.212

Source: Korea Industrial Research Institute (1990).

* total expenditure between 1982 and 1988.

** annual arithmetic average between 1982 and 1988.

Table 3. R&D Intensity (=R&D/Sales) and Education Level in Korea: 1982 and 1988

(%)

R&D Intensity	Primary & Middle	High School	2-year College	4-year College	Total
			1982		
			Male		
< 1	30.04	22.61	1.81	5.52	59.99
	50.08	37.69	3.02	9.21	100
≥ 1	17.28	16.78	1.36	4.60	40.01
	43.18	41.93	3.40	11.48	100
			Female		
< 1	57.39	9.32	0.25	0.13	67.09
	85.54	13.90	0.37	0.19	100
≥ 1	22.97	9.71	0.16	0.08	32.91
	69.79	29.49	0.49	0.24	100
			Male		
< 1	20.07	27.18	2.30	6.11	55.67
	36.06	48.83	4.14	10.97	100
≥ 1	10.88	23.73	3.14	7.08	44.33
	24.54	52.41	7.09	15.96	100
			Female		
< 1	39.96	18.17	0.52	0.46	59.11
	67.60	30.74	0.88	0.78	100
≥ 1	12.70	27.54	0.37	0.27	40.89
	31.07	67.36	0.90	0.67	100

Source: Korean Occupational Wage Survey, 1982 and 1988.

Table 4. Total R&D Expenditures
across Industries in OECD Countries*: 1978-1987

Unit: Million US Dollar

Industries	Industry of Manufacture		Industry of Use	
	Total R&D**	Percentage of Output (%)***	Total R&D**	Percentage of Output (%)***
Mining	5,719	1.27	5,551	2.71
Food, Drink, & Tobacco	14,667	0.23	6,435	0.10
Textiles & Clothing	4,687	0.21	5,318	0.21
Wood, Cork, & Furniture	2,764	0.18	2,053	0.16
Paper & Printing	7,461	0.19	8,228	0.29
Chemicals	82,387	2.95	5,656	0.20
Drugs	45,551	2.88	20,595	1.13
Petroleum Refineries	23,945	0.75	2,619	0.10
Rubber & Plastics	15,421	1.07	9,659	0.67
Stone, Clay & Glass	11,353	0.81	2,560	0.19
Ferrous Metals	16,210	0.71	3,728	0.20
Non-ferrous Metals	7,989	0.83	2,225	0.23
Fabricated Metals	12,293	0.41	12,388	0.42
Office Machinery & Computers	61,058	1.17	11,738	0.28
Electrical & Electronic Mach.	198,319	5.55	23,964	0.64
Other Manufacturing	6,720	1.14	2,793	0.72

Source: Evenson, Putnam and Kortum (1990), and
United Nations, *Industrial Statistics Yearbook*, various years.

* U.S., Japan, West Germany, France, and United Kingdom.

** total expenditure between 1978 and 1987 (1980 constant price).

*** annual arithmetic average between 1978 and 1987.

Table 5. OLS Estimates of Earnings Equation
with Total Factor Productivity across Industries
in Korea: 1982 (Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.113 (131)	0.086 (49)		
High School Dummy			0.388 (68)	0.226 (19)
2-year College Dummy			0.727 (52)	0.655 (21)
4-year College Dummy			1.140 (137)	0.986 (56)
Experience	0.080 (86)	0.079 (87)	0.078 (87)	0.078 (87)
$Experience^2/100$	-0.137 (56)	-0.137 (57)	-0.136 (57)	-0.136 (58)
Total Factor Productivity (=TFP)	0.009 (6.3)	-0.071 (15)	0.010 (7.1)	-0.015 (8.2)
TFP × Education (=years of schooling)		0.008 (17)		
TFP × High School Dummy				0.047 (15)
TFP × 2-year College Dummy				0.022 (2.7)
TFP × 4-year College Dummy				0.044 (10)
R^2	0.479	0.484	0.505	0.509
F	2922	2708	2703	2198
N	31,811			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

(Continued on the next page.)

(Table 5: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.089 (74)	0.042 (18)		
High School Dummy			0.414 (68)	0.173 (15)
2-year College Dummy			0.769 (27)	0.644 (10)
4-year College Dummy			1.131 (29)	1.145 (12)
Experience	0.040 (40)	0.040 (40)	0.039 (39)	0.039 (40)
$Experience^2/100$	-0.101 (35)	-0.100 (35)	-0.100 (35)	-0.099 (35)
Total Factor Productivity (=TFP)	0.056 (35)	-0.078 (13)	0.056 (35)	0.028 (14)
TFP × Education (=years of schooling)		0.015 (23)		
TFP × High School Dummy				0.076 (23)
TFP × 2-year College Dummy				0.043 (2.93)
TFP × 4-year College Dummy				0.009 (0.42)
R^2	0.346	0.361	0.349	0.365
F	1137	1108	963	826
N	21,546			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

Table 6. OLS Estimates of Earnings Equation
with R & D Expenditures (IOM) as a Percentage of Sales
across Industries in Korea: 1988
(Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.091 (120)	0.082 (66)		
High School Dummy			0.283 (58)	0.268 (32)
2-year College Dummy			0.508 (54)	0.491 (29)
4-year College Dummy			0.925 (132)	0.941 (77)
Experience	0.077 (103)	0.078 (103)	0.077 (106)	0.077 (106)
$\text{Experience}^2/100$	-0.128 (65)	-0.129 (65)	-0.133 (69)	-0.133 (69)
(R&D/Sales) in Korea (%) (=R&D)	0.008 (3.6)	-0.077 (7.8)	0.008 (3.7)	0.002 (0.35)
R&D × Education (=years of schooling)		0.007 (8.9)		
R&D × High School Dummy				0.012 (2.05)
R&D × 2-year College Dummy				0.013 (1.35)
R&D × 4-year College Dummy				-0.009 (1.16)
R^2	0.464	0.465	0.500	0.500
F	3132	2861	3014	2413
N	36,180			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

(Continued on the next page.)

(Table 6: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.045 (61)	0.048 (41)		
High School Dummy			0.189 (51)	0.200 (34)
2-year College Dummy			0.428 (26)	0.466 (16)
4-year College Dummy			0.812 (44)	0.751 (23)
Experience	0.026 (46)	0.026 (46)	0.026 (46)	0.025 (45)
Experience^2/100	-0.060 (38)	-0.060 (37)	-0.059 (37)	-0.059 (37)
(R&D/Sales) in Korea (%) (=R&D)	0.013 (7.8)	0.036 (4.9)	0.018 (11)	0.023 (8.4)
R&D × Education (=years of schooling)		-0.002 (3.2)		
R&D × High School Dummy				-0.008 (2.2)
R&D × 2-year College Dummy				-0.031 (1.66)
R&D × 4-year College Dummy				0.046 (2.2)
R^2	0.251	0.252	0.268	0.269
F	968	881	881	706
N	28,855			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

Table 7. OLS Estimates of Earnings Equation
with R & D Expenditures (IOM) as a Percentage of Outputs
across Industries in OECD Countries: 1988
(Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.090 (118)	0.089 (93)		
High School Dummy			0.278 (57)	0.293 (49)
2-year College Dummy			0.500 (53)	0.523 (42)
4-year College Dummy			0.915 (131)	0.961 (105)
Experience	0.078 (105)	0.078 (105)	0.078 (108)	0.078 (108)
$Experience^2/100$	-0.130 (66)	-0.131 (66)	-0.135 (71)	-0.134 (71)
(R&D/Outputs) by IOM in OECD countries (%) (=R&D)	0.018 (17)	0.008 (1.69)	0.018 (17)	0.232 (13)
R&D × Education		0.001 (2.15)		
R&D × High School Dummy				-0.014 (4.9)
R&D × 2-year College Dummy				-0.018 (3.8)
R&D × 4-year College Dummy				-0.029 (8.1)
R^2	0.468	0.468	0.504	0.505
F	3183	2895	3060	2457
N	36,180			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

(Continued on the next page.)

(Table 7: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.044 (61)	0.046 (52)		
High School Dummy			0.186 (50)	0.191 (43)
2-year College Dummy			0.426 (26)	0.439 (21)
4-year College Dummy			0.811 (44)	0.788 (34)
Experience	0.026 (46)	0.026 (46)	0.026 (46)	0.025 (45)
Experience^2/100	-0.060 (38)	-0.060 (37)	-0.060 (38)	-0.059 (37)
(R&D/Outputs) by IOM in OECD countries (%) (=R&D)	0.007 (9.7)	0.017 (5.0)	0.010 (13)	0.112 (9.2)
R&D × Education		-0.001 (2.94)		
R&D × High School Dummy				-0.003 (1.87)
R&D × 2-year College Dummy				-0.009 (1.02)
R&D × 4-year College Dummy				0.015 (1.59)
R^2	0.252	0.252	0.270	0.270
F	972	885	886	710
N	28,855			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

Table 8. OLS Estimates of Earnings Equation
with R & D Expenditures (IOU) as a Percentage of Outputs
across Industries in OECD Countries: 1988
(Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.095 (126)	0.106 (111)		
High School Dummy			0.307 (63)	0.357 (59)
2-year College Dummy			0.534 (57)	0.593 (45)
4-year College Dummy			0.947 (137)	1.025 (104)
Experience	0.077 (105)	0.076 (105)	0.077 (108)	0.076 (108)
Experience^2/100	-0.129 (67)	-0.129 (67)	-0.133 (71)	-0.133 (71)
(R&D/Outputs) by IOU in OECD countries (%) (=R&D)	0.106 (34)	0.290 (27)	0.093 (31)	0.129 (34)
R&D × Education		-0.020 (18)		
R&D × High School Dummy				-0.088 (13)
R&D × 2-year College Dummy				-0.112 (5.6)
R&D × 4-year College Dummy				-0.147 (10)
R^2	0.480	0.485	0.512	0.516
F	3345	3098	3166	2569
N	36,180			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

(Continued on the next page.)

(Table 8: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.045 (63)	0.042 (37)		
High School Dummy			0.193 (54)	0.177 (31)
2-year College Dummy			0.427 (26)	0.408 (16)
4-year College Dummy			0.810 (44)	0.733 (24)
Experience	0.026 (46)	0.026 (46)	0.025 (45)	0.025 (45)
$Experience^2/100$	-0.060 (38)	-0.061 (38)	-0.059 (37)	-0.060 (38)
(R&D/Outputs) by IOU in OECD countries (%) (=R&D)	0.048 (8.6)	-0.041 (1.66)	0.058 (11)	0.035 (4.5)
R&D x Education		0.009 (4.2)		
R&D × High School Dummy				0.044 (4.0)
R&D × 2-year College Dummy				0.053 (1.05)
R&D × 4-year College Dummy				0.193 (3.2)
R^2	0.252	0.252	0.268	0.269
F	969	883	880	706
N	28,855			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

Appendix Tables

Table A.1. OLS Estimates of Earnings Equation with Total Factor Productivity across Industries in Korea: 1988 (Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.097 (152)	0.057 (47)		
High School Dummy			0.298 (71)	0.139 (17)
2-year College Dummy			0.525 (66)	0.334 (18)
4-year College Dummy			0.937 (166)	0.660 (58)
Experience	0.076 (120)	0.076 (121)	0.076 (123)	0.076 (124)
Experience^2/100	-0.130 (79)	-0.130 (80)	-0.135 (84)	-0.135 (84)
Total Factor Productivity (=TFP)	0.008 (8.6)	-0.115 (35)	0.075 (8.0)	-0.030 (19)
TFP × Education (=years of schooling)		0.011 (39)		
TFP × High School Dummy				0.047 (23)
TFP × 2-year College Dummy				0.056 (12)
TFP × 4-year College Dummy				0.075 (29)
R^2	0.444	0.458	0.478	0.487
F	4596	4424	4385	3633
N	57,533			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.
(Continued on the next page.)

(Table A.1: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.057 (74)	0.010 (7.0)		
High School Dummy			0.245 (62)	0.019 (2.67)
2-year College Dummy			0.515 (38)	0.254 (8.0)
4-year College Dummy			0.775 (52)	0.604 (17)
Experience	0.034 (59)	0.035 (61)	0.034 (58)	0.034 (60)
$Experience^2/100$	-0.085 (51)	-0.081 (51)	-0.084 (51)	-0.081 (51)
Total Factor Productivity (=TFP)	0.038 (32)	-0.136 (32)	0.038 (33)	-0.012 (7.0)
TFP × Education (=years of schooling)		0.017 (42)		
TFP × High School Dummy				0.086 (38)
TFP × 2-year College Dummy				0.089 (12)
TFP × 4-year College Dummy				0.065 (8.3)
R^2	0.321	0.353	0.332	0.360
F	1631	1714	1430	1293
N	34,546			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

Table A.2. OLS Estimates of Earnings Equation
with R & D Expenditures (IOM) as a Percentage of Sales
across Industries in Korea: 1982
(Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.109 (107)	0.104 (58)		
High School Dummy			0.366 (56)	0.357 (32)
2-year College Dummy			0.709 (42)	0.715 (24)
4-year College Dummy			1.155 (112)	1.141 (63)
Experience	0.083 (78)	0.083 (78)	0.081 (78)	0.081 (78)
$\text{Experience}^2/100$	-0.147 (51)	-0.147 (51)	-0.145 (52)	-0.145 (52)
(R&D/Sales) in Korea (%) (=R&D)	0.019 (5.1)	-0.029 (2.15)	0.022 (6.0)	0.017 (2.78)
R&D × Education (=years of schooling)		0.005 (3.7)		
R&D × High School Dummy				0.008 (0.99)
0&D × 2-year College Dummy				-0.004 (0.20)
R&D × 4-year College Dummy				0.012 (1.00)
R^2	0.477	0.477	0.509	0.509
F	1996	1817	1891	1513
N	21,893			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

(Continued on the next page.)

(Table A.2: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.078 (61)	0.092 (42)		
High School Dummy			0.356 (55)	0.418 (38)
2-year College Dummy			0.770 (21)	0.864 (13)
4-year College Dummy			1.296 (25)	1.308 (14)
Experience	0.041 (40)	0.041 (40)	0.040 (40)	0.040 (40)
$Experience^2/100$	-0.103 (35)	-0.103 (35)	-0.101 (35)	-0.102 (35)
(R&D/Sales) in Korea (%) (=R&D)	0.041 (15)	0.124 (12)	0.043 (16)	0.055 (17)
R&D × Education (=years of schooling)		-0.010 (8.0)		
R&D × High School Dummy				-0.042 (7.0)
R&D × 2-year College Dummy				-0.078 (1.70)
R&D × 4-year College Dummy				-0.011 (0.16)
R^2	0.242	0.245	0.250	0.252
F	597	551	519	420
N	28,855			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

Table A.3. OLS Estimates of Earnings Equation
with R & D Expenditures (IOM) as a Percentage of Outputs
across Industries in OECD Countries: 1982 (Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.108 (106)	0.107 (83)		
High School Dummy			0.361 (56)	0.370 (45)
2-year College Dummy			0.705 (42)	0.725 (33)
4-year College Dummy			1.147 (112)	1.162 (86)
Experience	0.083 (78)	0.084 (78)	0.081 (78)	0.081 (78)
$Experience^2/100$	-0.147 (52)	-0.147 (52)	-0.145 (52)	-0.145 (52)
(R&D/Outputs) by IOM in OECD countries (%) (=R&D)	0.023 (13)	0.016 (2.40)	0.024 (14)	0.029 (10)
R&D × Education		0.001 (1.11)		
R&D × High School Dummy				-0.007 (1.74)
R&D × 2-year College Dummy				-0.015 (1.55)
R&D × 4-year College Dummy				-0.011 (1.87)
R^2	0.480	0.481	0.513	0.513
F	2024	1840	1918	1535
N	36,180			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

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(Table A.3: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.078 (60)	0.084 (51)		
High School Dummy			0.353 (55)	0.381 (46)
2-year College Dummy			0.771 (21)	0.816 (18)
4-year College Dummy			1.292 (25)	1.266 (19)
Experience	0.041 (40)	0.041 (40)	0.040 (40)	0.040 (40)
Experience^2/100	-0.103 (35)	-0.103 (35)	-0.101 (35)	-0.102 (35)
(R&D/Outputs) by IOM in OECD countries (%) (=R&D)	0.021 (17)	0.051 (11)	0.022 (18)	0.026 (18)
R&D × Education		-0.004 (6.4)		
R&D × High School Dummy				-0.015 (5.4)
R&D × 2-year College Dummy				-0.037 (1.74)
R&D × 4-year College Dummy				0.017 (0.56)
R^2	0.245	0.246	0.253	0.254
F	606	556	527	424
N	28,855			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

Table A.4. OLS Estimates of Earnings Equation
with R & D Expenditures (IOU) as a Percentage of Outputs
across Industries in OECD Countries: 1982
(Dep. Var. = ln Hourly wage)
Male

Variables	I	II	III	IV
Education (=years of schooling)	0.111 (111)	0.121 (94)		
High School Dummy			0.385 (60)	0.437 (53)
2-year College Dummy			0.719 (44)	0.763 (36)
4-year College Dummy			1.166 (115)	1.251 (92)
Experience	0.082 (78)	0.081 (78)	0.079 (78)	0.079 (78)
$Experience^2/100$	-0.146 (52)	-0.146 (52)	-0.144 (53)	-0.144 (53)
(R&D/Outputs) by IOU in OECD countries (%) (=R&D)	0.132 (29)	0.297 (20)	0.122 (28)	0.158 (30)
R&D × Education		-0.018 (12)		
R&D × High School Dummy				-0.104 (9.9)
R&D × 2-year College Dummy				-0.083 (3.0)
R&D × 4-year College Dummy				-0.165 (9.1)
R^2	0.496	0.499	0.501	0.529
F	2154	1983	1691	1635
N	36,180			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.

(Continued on the next page.)

(Table A.4: Continued from the previous page.)

Female

Variables	I	II	III	IV
Education (=years of schooling)	0.077 (60)	0.081 (41)		
High School Dummy			0.352 (55)	0.373 (37)
2-year College Dummy			0.758 (21)	0.850 (16)
4-year College Dummy			1.275 (25)	1.235 (17)
Experience	0.040 (39)	0.040 (39)	0.039 (39)	0.039 (39)
Experience^2/100	-0.101 (35)	-0.102 (35)	-0.100 (34)	-0.100 (34)
(R&D/Outputs) by IOU in OECD countries (%) (=R&D)	0.153 (18)	0.235 (7.4)	0.155 (19)	0.171 (17)
R&D x Education		-0.010 (2.66)		
R&D × High School Dummy				-0.049 (4.0)
R&D × 2-year College Dummy				-0.221 (2.38)
R&D × 4-year College Dummy				0.077 (0.74)
R^2	0.246	0.246	0.254	0.254
F	611	556	530	425
N	28,855			

t - values are in parentheses.
Other variables included are constant, regional dummies and firm size dummies.