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TECHNOLOGICAL CHANGE AND DEMAND FOR SKILLS IN DEVELOPING COUNTRIES: AN EMPIRICAL INVESTIGATION OF THE REPUBLIC OF KOREA'S CASE

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There are few studies that directly address the upskilling issues in developing countries. Since theoretical analyses of these issues usually yield different results, upskilling in developing counties, and the factors of upskilling, if any, are rather empirical questions. This study shows that upskilling that occurs in developed countries in terms of the ratio of the number of white-collar workers to that of blue-collar workers also occurred in the Republic of Korea, one of developing countries. Increasing demand for highly-skilled workers reflected in their employment and wage shares can be largely explained by "within industry" shifts, not by "between industry" shifts, especially in the manufacturing industry. To further investigate the causes of these shifts, changes in white-collar shares are regressed on the capital-output and R&D-sales ratio. Estimated coefficients are all positive, suggesting capital-skill complementarities and skill-biased technological change.

I. INTRODUCTION

IN developed countries, it is observed that supply of highly-skilled labor has increased while their employment and/or wage shares have also increased. In other words, the growth rate of demand for highly-skilled labor exceeds that of supply. Broadly speaking, there are two possible explanations for this increase in the demand for highly-skilled labor: technology and trade.

It is often argued that an increase in demand for highly-skilled labor is closely correlated with technological progress. For example, rapid progress in information technology creates new demand for computer-related labor. Haskel (1996) shows that about half of the skill premiums in the United Kingdom during the 1980s can be explained by the introduction of computers. Siegel (1997) shows that there exists a positive relationship between expenditure on computers and the quality indices of labor. While it is generally accepted that technological progress requires new labor skills, there are ongoing discussions regarding to what degree increased demand for highly-skilled labor results from technological progress. It is not easy to construct a theoretical model that simultaneously considers demand and supply of heterogeneous labor. Building a model which links demand for labor to technological progress is relatively simple, but taking the heterogeneity of labor into consideration is difficult.

There are also discussions on relationships between skill upgrading and globalization. As trade between developing and developed countries increases with globalization trends, exports from developing countries to developed countries of largely labor-intensive goods, can change the industry structure within developed countries, focusing more on skills or capital-oriented industries. The impact of globalization on developing countries is more complicated. It is expected that demand for low-skilled labor will increase as low-skill-based exports from these countries increase. If this increase in demand for low-skilled labor is greater than supply, wages and employment of low-skilled labor will increase. Increased capital imports from developed countries will lower domestic prices of capital in developing countries, which will generate more demand for capital. Demand for highly-skilled labor will also increase if capital-skill complementarities hold. While it is not generally accepted that capital-skill complementarities also exist in developing countries, Goldin and Katz (1998) present this possibility. Increased demand for capital will also increase demand for highly-skilled labor, and if demand grows faster than supply, their wages will also increase. Hence, it is an empirical question whether shares in employment and wage of highly- and low-skilled labor in developing countries will increase or not. In practice, empirical investigation on this subject seems to be difficult due to the absence of measures that appropriately reflect skill levels, and deficiencies in consistently constructed data, including indicators of technological progress and detailed components of international trade.

This paper studies the similarities and differences of skill upgrading between the Republic of Korea and the OECD member countries by analyzing the changes in Korea's employment and wage structure by industry and occupation. This paper first examines whether skill upgrading has been observed in Korea, and then focuses on finding the cause of this phenomenon.

II. PREVIOUS STUDIES

In developed countries, it is observed that the employment and wage shares of highly-skilled workers have increased during the 1980s and 1990s. The term "skill," which generally reflects the level of human capital in labor markets, is a multi-dimensional concept. There are two broad approaches to the analysis of work-related skills, viz., to treat them as attributes of individuals, or as requirements of jobs. Studies seeking to explain skill-biased wage premiums usually adopt the first approach, identifying supply and demand side determinants of wage changes in different groups of individuals: for example, those with a certain level of education. A related set of studies seeks to explain changes in the wage-bill share (including both price and quantity effects) of skilled workers generally defined by occupational group. The second approach examines directly the changing skill mix of labor force, identifying within and between occupations as well as within and between industry shifts (O'Connor and Lunati 1999).

Skill upgrading was a central research issue during the 1990s. In the United States, the earnings differentials between high school and college graduates rose by more than 10 percentage points throughout the 1980s (Murphy and Welch 1989, 1992; Bound and Johnson 1992). Berman, Bound, and Griliches (1994) analyzed the changing shares of production and non-production workers in the U.S. 450 manufacturing industries during the 1980s. They argued that a main cause of the shift in demand from unskilled and toward skilled labor is labor-saving technological progress. The grounds for this conclusion are: (1) the shift is due to increased use of skilled workers within industries rather than to a reallocation of employment between industries; (2) demand for trade and defense is associated only with small employment effects; and (3) increased demand for non-production labor is closely related with computer and R&D expenditures.

Colecchia and Papaconstantinou (1996) carried out an extensive study on skill upgrading in the OECD countries. They showed that in most OECD countries, the proportion of highly-skilled labor increased rapidly during the 1980s, but that of low-skilled labor increased at a lower rate or even decreased. Skill upgrading was evident in the manufacturing industries and a shift to highly-skilled labor was attributed primarily to higher demand within industries. Their empirical results suggest that skill upgrading was more clearly observed in industries with high and increasing rates of patents and R&D expenditures.

Machin and Van Reenen (1998) analyzed changes in employment and wage structures by occupation in seven OECD countries including the United States, Japan, and Germany. They showed that the changes in employment and wage shares are closely related to R&D intensity, which implies that a skill-biased technological change boosts demand for highly-skilled labor.

The aforementioned studies all show that the skill upgrading, widely observed in almost all developed countries, is closely related to the skill-biased technological change.[1] It appears that there have been very few studies of technology-skill complementarities in developing countries. Goldin and Katz (1998) and Katz (1999) argue that the capital-skill complementarities and skill-biased technological change were also observed in the early stage of U.S. economic development. If these views are correct, then we might expect similar technology-skill complementarities to occur in developing countries.

Berman, Bound, and Machin (1998) examined trends in demand for industrial

[1] Unlike these studies, Wolff (1996) finds that much of growing demand for skills can be attributed to inert-industry shifts (hence perhaps to sector-biased, not pervasive skill-biased technological change).

skills (as measured by the employment ratio of non-production to production workers) from a cross section of OECD and other countries throughout the 1980s, and found a widespread tendency toward rising ratios even in developing countries. Moreover, they found that the earnings ratio of non-production workers to production workers changed little in these countries despite the strong expansion in the ranks of educated workers. They cited skill-biased technological change and capital-skill complementarities as possible explanations.

Tan and Batra (1997) used Census of Manufacturers data to examine the relationship between measures of technology and skills demand in Colombia, Mexico, and Taiwan. Their hypothesis is that skill-biased wage differentials result from firms' technology-generating activities, such as R&D, worker training, and exports. They found that higher skill premiums are more strongly correlated with R&D and training than with exports.

Unlike developed countries, wage differentials between highly-educated and low-educated labor in Korea have decreased since the middle of the 1970s. Table I shows that the proportion of the average wage of college graduates over high school graduates was 2.10 in 1986, and 1.47 in 1996 (Kim and Topel 1995). Fields and Yoo (2000) showed that the wage differentials between these workers also decreased in a regression context.

TABLE I

AVERAGE WAGE DIFFERENTIALS BY EDUCATION

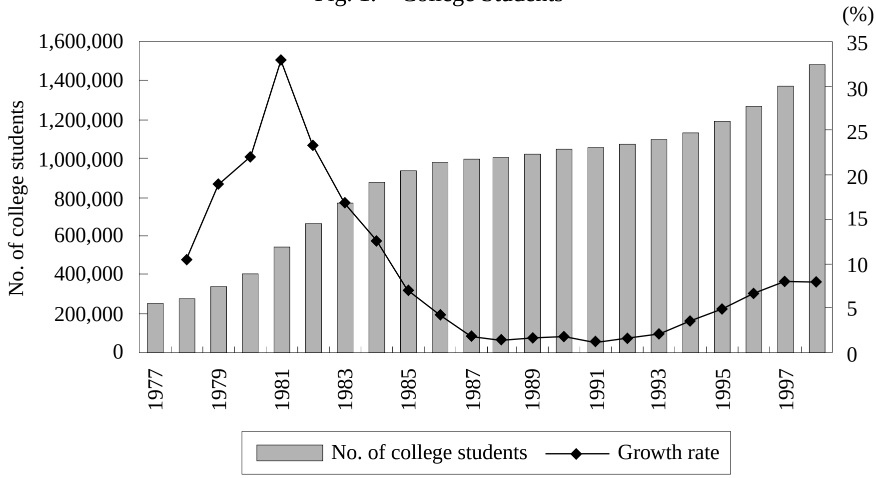
(High school graduate = 100)

	1976	1981	1986	1991	1996
Total	87.92	97.12	107.12	108.80	108.53
Male	113.30	122.53	129.52	126.80	121.67
Female	49.76	56.60	64.22	71.06	74.81
Less than middle school	59.12	73.33	82.21	88.97	89.44
Male	75.97	95.52	103.02	107.62	106.05
Female	42.98	50.31	55.50	63.33	63.21
High school	100.00	100.00	100.00	100.00	100.00
Male	111.99	115.52	117.12	116.07	112.11
Female	66.34	65.17	65.56	70.38	71.97
Two-year college	145.27	140.78	128.17	116.70	107.70
Male	156.31	150.27	135.32	126.72	117.48
Female	100.82	101.69	101.14	86.09	84.57
College or above	229.66	212.88	209.67	168.46	147.23
Male	235.64	218.62	216.00	172.65	151.42
Female	161.11	145.19	153.14	126.25	116.53

Sources: Ministry of Labor, *Survey Report on Wage Structure*; and National Statistical Office, *Social Indicators in Korea, 1999*.

Note: Based on a survey of establishments with ten or more regular employees.

Fig. 1. College Students



Source: Ministry of Education, *Statistical Yearbook of Education*, various years.

These studies emphasize that the nonincreasing wage differentials are due largely to increased supply of highly-educated labor during this period (see Figure 1), but do not explicitly take demand for highly-educated workers into consideration. And due to a rapid increase in the number of highly-educated workers during this period, careful attention seems to be needed for examining the relationship between the level of education and that of skills especially in Korea.

III. KOREA'S UPSKILLING: A FIRST LOOK

A. *Data and Some Adjustment*

It is not easy to construct consistent and reliable time-series data by industry and occupation in the Republic of Korea due to limited availability of information and time-inconsistent industry and/or occupation classification systems. There are no officially published industry and occupation employment matrices in consistent time-series contexts in two- or three-digit industry levels. The standard classification systems of industries and occupations are frequently revised, but it is not always possible to construct a consistent employment-by-occupation matrix across the different classification systems. Furthermore, there is no official capital stock data. R&D data collected by the Ministry of Science and Technology is based on a different industry classification system.

The Korea's standard occupation classification system was first established in 1963, and has been revised five times: in 1966, 1970, 1974, 1992, and 2000. The second revision in 1970 was based on the International Standard Classification of

Occupations 1968 (ISCO-1968), and the fourth revision in 1992 was based on the International Standard Classification of Occupations 1988 (ISCO-1988). According to the definition of white-collar and blue-collar workers in Colecchia and Papaconstantinou (1996), group 0/1 (professional and technical), group 2 (administrative and managerial), group 3 (clerical and related workers), group 4 (sales workers), and group 5 (service workers), based on ISCO-1968, can be classified as white-collar workers, while the remaining groups, group 6 (agricultural workers) and groups 7/8/9 (transport/production workers, laborers) can be classified as blue-collar workers. And group 1 (legislators, senior officials, and managers), group 2 (professionals), and group 3 (technicians and associate professionals), based on ISCO-1988, can be classified as white-collar highly-skilled workers (WCHS); group 4 (clerks, service workers) and group 5 (shop and market sales workers) as white-collar low-skilled (WCLS); group 6 (skilled agricultural and fishery workers) and group 7 (crafts and related trade workers) as blue-collar highly-skilled (BCHS); and group 8 (plant and machine operators and assemblers) and group 9 (elementary occupation) as blue-collar low-skilled (BCLS). Group 1 through group 3 can be classified as highly-skilled and group 4 through group 9 as low-skilled.[2] Group 1 through group 5 can be classified as white-collar and group 6 through group 9 as blue-collar. Since the Korea's occupation classification systems are based on both ISCO-1968 and ISCO-1988, we follow these two different lines of definitions for white-collar and blue-collar workers.

The Korean Standard Industry Classification (KSIC) was first established in 1963 and has been revised seven times: in 1965, 1968, 1970, 1975, 1984, 1991, and 2000. The third revision of KSIC in 1970 was based on the International Standard Industrial Classification 1968 (ISIC-1968) and the sixth revision in 1991 was based on ISIC-1989. We will use wage and employment data collected by the Ministry of Labor, whose industry classification is based on KSIC. The KSIC based on ISIC-1968 and that based on ISIC-1989 are hard to combine in a consistent way. The KSIC based on ISIC-1968 divides the industries into 9 groups, 35 divisions, 283 subdivisions, and 1,047 minor divisions, while that based on ISIC-1989 divides the industries into 17 groups, 60 divisions, 293 subdivisions, and 1,193 minor divisions. Without further detailed information, it is almost impossible to construct time-consistent industry classifications in the subdivision level (three-digit level).[3] We will use division level data (two-digit level).

[2] Examples of highly-skilled occupations are: legislators and senior officials; corporate managers; general managers; physical, mathematical, and engineering science professionals; life science and health professionals; and teaching professionals.

[3] From the fifth revision of occupation classification systems and the seventh revision of industry classification systems, linkage tables before and after the revisions are provided by the National Statistical Office.

TABLE II

EMPLOYMENT AND OUTPUT SHARES BETWEEN 1985 AND 1995

(%)

	Share			Growth Rate		
	1985	1990	1995	1985–90	1990–95	1985–95
Agriculture, etc.	25.5	18.5	14.4	–2.4	–3.4	–2.9
	(14.4)	(8.3)	(5.6)	(–0.8)	(10.0)	(0.1)
Mining	1.1	0.5	0.3	–12.8	–9.3	–11.0
	(0.8)	(0.7)	(0.6)	(8.7)	(4.7)	(6.7)
Manufacturing	22.9	27.4	24.0	7.8	–1.1	3.3
	(20.8)	(24.5)	(33.1)	(14.5)	(16.1)	(15.3)
Services	50.6	53.6	61.4	5.1	4.4	4.8
	(64.0)	(66.5)	(60.8)	(11.6)	(7.4)	(9.5)
Total	100.0	100.0	100.0	3.9	1.6	2.8
	(100.0)	(100.0)	(100.0)	(10.8)	(9.4)	(10.1)

Source: Chang (1999).
Note: The figures are based on the employment shares, while the figures in parentheses are based on the output shares (in 1996 real valued added).

B. *Changes in Korea's Employment Structure by Industry and Occupation*

Table II shows the changes in employment and output shares in Korea. Since 1985, the amount of employment in agriculture, forestry, and fishing has decreased, while that in the service industry has continued to increase. The employment in the manufacturing industry has increased during the 1980s, but decreased since the 1990s. In 1985, the shares of employment in agriculture, forestry, and fishing, manufacturing, and service industries were 25.5 per cent, 22.9 per cent, and 50.6 per cent, respectively. Between 1985 and 1995, the average growth rate of employment in each industry was –2.9 per cent, 3.3 per cent, and 4.8 per cent, respectively. In 1995, the proportion of employment in each industry came to 14.4 per cent, 24.0 per cent, and 61.4 per cent, respectively.

While the growth rate of employment in each industry has varied, the growth rates of output (measured by real value added) have been positive in all industries. The annual growth rate of employment in the manufacturing industry was 3.3 per cent between 1985 and 1995, and that of output was 15.3 per cent. The share of employment in manufacturing industry was 24.0 per cent in 1995 and that of output reached 33.1 per cent in 1995. On the other hand, the annual growth rate of employment in the service industry was 4.8 per cent between 1985 and 1995, and that of output was 9.5 per cent. The output share of service industry has decreased from 64.0 per cent in 1985 to 60.8 per cent in 1995.

Table III shows the changing shares of white-collar workers in Korea based on the *Survey Report on Wage Structure* collected by the Ministry of Labor. It shows

TABLE III

CHANGES IN WHITE-COLLAR SHARES

(%; % points)

	All Industry		Manufacturing	
	Employment	Wage	Employment	Wage
1976	29.35	47.85	17.58	32.48
1981	35.59 (6.24)	50.44 (2.59)	20.38 (2.80)	32.02 (–0.46)
1986	40.69 (5.10)	55.60 (5.16)	24.87 (4.49)	36.49 (4.47)
1991	48.44 (7.75)	54.80 (–0.80)	35.57 (10.70)	38.77 (2.28)
1996	52.46 (4.02)	60.09 (5.29)	35.80 (0.23)	41.50 (2.73)

Source: Ministry of Labor, *Survey Report on Wage Structure*.

Notes: 1. Based on a survey of establishments with ten or more regular employees.
2. Data until 1991 is based on the ISIC-1968 and ISCO-1968 and that of 1996 is based on the ISIC-1989 and ISCO-1988.
3. Figures in parentheses are increases during each period.

that employment and wage shares of white-collar workers have increased in all industries since 1976. The employment and wage shares of white-collar workers were 29.35 per cent and 47.85 per cent, respectively, in 1976 as compared with 40.69 per cent and 55.60 per cent, respectively, in 1986, and 52.46 per cent and 60.09 per cent, respectively, in 1996. While the average annual growth rate of the employment share of the white-collar workers was 2.95 per cent between 1976 and 1996, the average growth rate of wage share was 1.15 per cent. This suggests that during this period, while the number of white-collar workers increased, the relative wage of white-collar workers over the blue-collar workers decreased.

While there were general upward trends in employment and wage shares during this period, the wage share of white-collar workers decreased from 55.60 per cent in 1986 to 54.80 per cent in 1991, despite the fact that their employment share increased drastically from 40.69 per cent in 1986 to 48.44 per cent in 1991. The democracy movement that strengthened the labor unions' negotiating power during this period seems to be one of the main reasons. Also, increased supply of college graduates resulting from college education reform in the early 1980s seems to be a primary factor of this reverse trend in wage shares. Figure 1 shows that the number of college students increased drastically in the late 1970s and early 1980s. The number of college students more than doubled from 1976 to 1981. It almost doubled again during 1981 to 1986. This increased supply of college students seems to be a main cause of a decrease in the relative wage of the white-collar workers.

In the manufacturing industry, the employment and wage shares of white-collar workers were 17.58 per cent and 32.48 per cent in 1976, 24.87 per cent and 36.49 per cent in 1986, and 35.80 per cent and 41.50 per cent in 1996. While there were general upward trends in these shares, the employment share stabilized between

TABLE IV

INTERNATIONAL COMPARISON OF EMPLOYMENT STRUCTURES IN MANUFACTURING

(%)

		WCHS	WCLS	BCHS	BCLS
Australia	1986	23.49	15.52	29.03	31.96
	1991	26.21	15.87	28.82	29.01
Canada	1986	17.71	14.74	20.23	46.67
	1991	20.57	16.28	19.16	42.87
United States	1988	17.66	16.44	20.82	45.08
	1994	18.00	14.45	22.11	45.44
Japan	1985	13.22	17.90	53.21	15.67
	1990	14.54	20.04	50.83	14.58
Germany	1985	19.70	14.11	35.71	30.48
	1990	21.35	14.10	35.92	28.63
Korea	1993	13.18	20.13	29.97	36.54
	1997	18.32	20.05	21.08	40.54

Sources: The data except for Korea are based on OECD (1998). The data for Korea are based on the *Survey Report on Wage Structure* (Ministry of Labor).
Note: WCHS denotes white-collar highly-skilled; WCLS, white-collar low-skilled; BCHS, blue-collar highly-skilled; and BCLS, blue-collar low-skilled.

1991 and 1996. It can be also observed that while the employment share was almost unchanged in this period, the wage share of white-collar workers increased from 38.77 per cent in 1991 to 41.50 per cent in 1996.

In the manufacturing industry, there are some distinct features in each period. Between 1976 and 1981, while the employment share of white-collar workers increased by 2.80 per cent, their wage share dropped slightly by 0.46 per cent. Between 1986 and 1991, the employment share increased by 10.70 per cent, but the wage share increased only 2.28 per cent. This trend was not observed in the 1990s. The employment share increased slightly by 0.23 per cent between 1991 and 1996, but the wage share increased 2.73 per cent, which is greater than the employment share. These features suggest that unlike the 1980s when the growth of supply was greater than that of demand, the growth rate of demand might have been greater than that of supply in the 1990s.

Table IV compares Korea's occupational structure in the manufacturing industry with that of OECD countries. The proportion of white-collar workers in Korea was 33.31 per cent in 1993 and 38.37 per cent in 1997. This figure in 1993 appears to be similar to that of other OECD countries, such as the United States with 32.45 per cent in 1994, Japan with 34.58 per cent in 1990, and Germany with 35.45 per cent in 1990. In fact, Korea's white-collar proportion in 1997 was greater than that of all the OECD countries but Australia. It is very interesting that the fact that the share of white-collar workers in Korea increased by 5.06 per cent between 1993 and 1997 can mostly be attributed to an increase in the number of white-collar highly-skilled workers. On the other hand, during the same period the share of blue-collar low-skilled workers increased by 4.0 per cent, and that of blue-collar highly-skilled workers decreased by 8.89 per cent. Hence, in the 1990s Korea experienced a rapid growth in white-collar highly-skilled labor and a dramatic drop in blue-collar highly-skilled labor.

Even with the rapid growth of WCHS, the proportion of WCHS to WCLS is far less than that of OECD countries except Japan. For example, the ratio of WCHS to WCLS is 1.65 for Australia in 1991, 1.25 for the United States in 1994, and 1.51 for Germany in 1990. For Korea, this ratio is 0.65 in 1993 and 0.91 in 1997.

The proportion of highly-skilled workers for Korea in 1997 is 39.40 per cent, which is far less than that of OECD countries such as Germany with 57.27 per cent in 1990, Japan with 65.37 per cent in 1990, and Australia with 55.03 per cent in 1991. This low level proportion of highly-skilled labor is similar to that of the United States. Hence, Korea's occupational structure compared to OECD countries can be characterized by a low proportion of highly-skilled labor, a high proportion of white-collar workers, a low share of highly-skilled workers within white-collar workers, and a high share of low-skilled workers within blue-collar workers. The structure of a high share of low-skilled workers within white-collar workers is similar to that of Japan, and the structure of a high share of low-skilled workers within blue-collar workers is similar to that of the United States.

IV. EMPIRICAL INVESTIGATION

A. *Within Industry and Between Industry Decomposition*

Berman, Bound, and Griliches (1994) argued that the causes of skill upgrading in the United States could be analyzed by "between " and "within" industries' shifts. Increases in international trade and military buildup would work primarily by shifting the derived demand for labor between industries from those intensive in production workers to those intensive in non-production workers. On the other hand, biased technological change would shift the skill composition of labor demand within industries. For this reason, they proposed a general method that decomposes an overall shift within the economy into "within industry" and "between industry" shift. This decomposition enables us to study the factors of changes in employment and wage shares between production and non-production workers.

Their decomposition method can be applied to Korea's case. Korea is a small open economy that heavily relies on exports in its path to economic development. The U.S. experience of increased demand in defense-related industries and more imports from developing countries is analogous to Korea's experience of changed demand for Korean-made goods from foreign countries. As in the United States, changes in demand for final products would result in labor shifts between industries in Korea. While demand shifts in the United States resulted in increased demand in non-production workers, the result of demand shifts in Korea is somewhat ambiguous primarily due to the mixture of income and substitution effects of economic growth.

Berman, Bound, and Griliches's (1994) decomposition method is based on the premise that the variance can be divided into the expectation of conditional variance and variance of conditional expectation. Let $P_n = E_n / E$ be an aggregate proportion of non-production workers, $P_{ni} = E_{ni} / E_i$ be the proportion of non-production workers in industry i, $S_i = E_i / E$ be the employment share of industry i, and Δ be the change. The overall change in employment shares of non-production workers can be decomposed into the "within industries" and "between industries" shifts.

$$\Delta P_n = \sum_{i=1}^{n} \Delta S_i \bar{P}_{ni} + \sum_{i=1}^{n} \Delta P_{ni} \bar{S}_i.$$

The first term on the right reports a change in the aggregate proportion of non-production workers attributable to shifts in employment shares between industries with different proportions of non-production workers. The second term represents a change in the aggregate proportion attributable to changes in the proportion of non-production workers within each industry. A bar over a term denotes a mean over time.

Table V reports the decomposition results.[4] The results between 1976 and 1991 are based on the Korean Standard Industry Classification (KSIC) based on ISIC-1968, which subdivides the industries into 46 subdivisions, of which 28 are manufacturing industries. They are also based on the Korean Standard Occupation Classification (KSOC) based on ISCO-1968. The results between 1993 and 1997 are based on the KSIC based on ISIC-1989, which subdivides the industries into 129 subdivisions, of which 61 are manufacturing industries. They are also based on the KSOC based on ISCO-1988. The Korea's industry classification system underwent a major revision in 1991, and the continuity of industry classification before and after the revision in three-digit levels is not assured without extra information. Here, we analyzed each period separately.

In all industries between 1976 and 1981, the employment share of white-collar workers increased 6.242 per cent, of which 4.757 per cent was between industries shifts and 1.484 per cent was within industries shifts. During the same period, the wage share of white-collar workers increased 2.590 per cent, of which 3.768 per cent was between industries shifts and −1.179 per cent was within industries shifts. These facts imply that in the late 1970s the shift from blue-collar workers to white-collar workers was largely explained by final demand shifts rather than technological change.

Between 1981 and 1986, changes in the employment shares of all industries are

[4] Due to limited data available, we could not calculate the wage share decomposition between 1993 and 1997.

TABLE V

DECOMPOSITION OF THE CHANGES IN THE SHARE OF WHITE-COLLAR WORKERS

			1976–81	1981–86	1986–91	1993–97
Employment	All Industries	Between	4.757	2.262	3.869	3.270
		Within	1.484	2.832	3.888	2.406
		Total	6.242	5.094	7.758	5.676
	Manufacturing	Between	0.758	0.152	1.353	0.396
		Within	2.047	4.333	8.346	4.509
		Total	2.805	4.486	9.699	4.905
Wage	All Industries	Between	3.768	1.805	0.377	—
		Within	–1.179	3.351	–1.171	—
		Total	2.590	5.156	–0.794	—
	Manufacturing	Between	0.717	–0.456	0.691	—
		Within	–1.177	4.927	1.594	—
		Total	–0.460	4.471	2.285	—

better explained by within industries shifts. That is a total increase in white-collar workers' employment share of 5.094 per cent, of which 2.832 per cent was within shifts and 2.262 per cent was between shifts. Since then, the explanatory power of within shift components has become somewhat weaker. Between 1993 and 1997, the employment share of white-collar workers increased by 5.676 per cent, of which 2.406 per cent was within shifts and 3.270 per cent was between shifts.

On the contrary, the explanatory power of within shifts is dominant in manufacturing industries throughout these periods. Between 1976 and 1981, the total increase of white-collar workers in manufacturing industries was 2.805 per cent, of which 2.047 per cent was within industries shifts. The within shifts explained 96.6 per cent of the total change between 1981 and 1986, 86.1 per cent between 1986 and 1991, and 91.9 per cent between 1993 and 1997.

These imply that the upskilling in Korea's manufacturing industries can also be explained by the within industries shifts, which reflect skill-biased technological change, not by the between industries shifts, which reflect changes in final demand. It is quite interesting that while upskilling in all industries is well explained by the between shifts, upskilling in manufacturing industries is mostly explained by the within shifts.

In terms of wage shares of white-collar workers, similar trends are observed, though the absolute levels are different. In all industries, wage shares of white-collar workers increased 2.590 per cent between 1976 and 1981, of which 3.768 per cent was between shifts and –1.179 per cent was within shifts. During this period, the between shift explains most of the wage share changes. Between 1981 and 1986, the change in white-collar workers wage share was 5.156 per cent, of which

1.805 per cent was between shifts and 3.351 per cent was within shifts. Hence during this period, the within shifts explain the wage share changes better than the between shifts. Between 1986 and 1991, the total wage share of white-collar workers decreased 0.794 per cent, of which 0.377 per cent was between shifts and –1.171 per cent was within shifts. In the manufacturing industries, between industries effects dominated the within effects between 1976 and 1981 and the within shifts effects dominated the between effects between 1981 and 1986. The within effects still largely explain the changes between 1986 and 1991.

These wage share decomposition results seem to be consistent with those of employment. In short, the Korea's upskilling in all industries is closely correlated with final demand shifts and skill upgrading in the manufacturing industries is largely due to skill-biased technological change.

It is consistent with the OECD countries' experiences that upskilling in the manufacturing industries can be explained largely by within shifts rather than between shifts. In the context of all industries, however, the explanatory power of the between shifts component in Korea is relatively larger than those in the OECD countries. According to Colecchia and Papaconstantinou (1996), the explanatory power of within shifts in all industries during the 1980s exceeds 70 per cent in most OECD countries, except Italy with 38.7 per cent and France with 58.4 per cent.[5]

This difference might be explained by rapid changes in Korea's industrial structure (and also the composition of exports and imports) during this period. This needs further study.

B. *Multivariate Analyses*

It has been shown that upskilling in Korea is largely explained by within industries shifts, especially in manufacturing industries. This section further investigates the factors of the within industries shifts by studying the share equation of a quasi-fixed cost function, as indicated in Brown and Christensen (1981) and Berman, Bound, and Griliches (1994) among others.

Assume that the cost function has a translog form, capital is fixed in the short run, and the employment of white-collar workers and blue-collar workers is variable. With the constant returns to scale production function, the change in wage shares of white-collar workers is a function of relative wages of white-collar workers to blue-collar workers and the capital-output ratio. Specifically it can be written as

$$\Delta S_i^w = \beta_0 + \beta_1 \Delta \ln(W_i^w / W_i^b) + \beta_2 \Delta \ln(K_i / Y_i) + \varepsilon_i,$$

where i indexes industry; ΔS^w denotes a change in the shares of white-collar wages

[5] The explanatory power of within shifts over the total change is 78.3 per cent (the United States, 1983–93), 84.5 per cent (Canada, 1981–91), 73.6 per cent (Japan, 1980–90), and 83.0 per cent (Australia, 1986–91). See Colecchia and Papaconstantinou (1996, p. 35).

in total wages; W^w and W^b denote the wages of white-collar and blue-collar workers, respectively; K and Y denote capital and value added, respectively.

The coefficient of relative wages β_1 is positive if the substitution elasticity between white-collar and blue-collar workers is below one. The capital-skill complementarities imply positive β_2. The residual from the regression can be regarded as changes in wage shares that cannot be explained by either changes in relative factor prices or the capital-output ratio. The constant term can be interpreted as biased technological change common to all industries, and the sum of constant and disturbance as that specific to each industry.

We exclude the relative wage term in our estimation equation as in Berman, Bound, and Griliches (1994) and add the proportion of R&D expenditure (*RD*) over the sales (*SD*) to reflect the industry specific factor which may lead biased technological change.[6] Our final estimation equation is

$$\Delta S_i^w = \beta_0 + \beta_1 \Delta \ln(K_i/Y_i) + \beta_2 \ln(RD_i/SD_i) + \varepsilon_i. \tag{1}$$

The data for employment and wages is based on the *Survey Report on Wage Structure* collected by the Ministry of Labor. For the capital stock, we used Pyo's (1988) estimates. In Pyo's estimates, industries are classified in the two-digit level by the KSIC based on ISIC-1968. For value added by industry, we used the estimates of the Bank of Korea. In the Bank of Korea's estimates, industries are classified using a time-consistent classification system throughout the relevant periods, but this system is different from the KSIC. For the R&D expenditure over the sales, we used the data collected by the Ministry of Science and Technology.[7] The R&D data is also based on different classification systems, which is not time-consistent. Since the capital stock, value added, and R&D expenditure over sales are only available

[6] This specification is largely based on that of Berman, Bound, and Griliches (1994) and Colecchia and Papaconstantinou (1996). It is hard to justify the exogeneity of relative wages, since the dependent variable is a wage share. The differences of relative wages between industries may represent those of skill mixtures of different industries, but most of them might reflect upskilling within industries. Under the assumption that the relative wage of white-collar workers to blue-collar workers adjusted by quality of labor remains unchanged, it can be excluded from the estimated equation without affecting the estimation results, except the constant. Finally there might be common factors that both affect capital investment decisions and unobserved disturbances (which are interpreted as technological change). This correlation between explanatory variables and disturbances may lead to inconsistency of an OLS estimate (which is called endogeneity bias problem). This problem may not be serious if we use annual data.

[7] An anonymous referee pointed out that if this R&D expenditure includes the purchase of research institute's buildings and land, an increase in the R&D expenditure might not directly affect demand for skilled labor. In Korea's data, R&D expenditures are composed of current expenditures and capital expenditures; the former includes labor cost, technology education, and reagent, and the latter includes machinery, buildings, and land. The proportion of expenditures on buildings and land–related costs over that of total R&D is relatively small and stays stable within the range of 5–7 per cent throughout the years. Hence the inclusion of the expenditures on land and buildings will not change the estimated result significantly.

TABLE VI

SUMMARY STATISTICS

	Explanation	Mean	Std. Dev.	Min.	Max.
W_1	Employment share (%)	5.570	7.286	0.567	37.374
W_2	Wage share (%)	6.621	5.580	0.614	29.531
Y_1	Changes in white-collar employment share (% p)	3.680	6.397	–11.370	19.892
Y_2	Changes in white-collar wage share (% p)	1.580	13.986	–30.389	32.433
$D1$	Dummy for changes between 1976 and 1981	0.250	0.437	0	1
$D2$	Dummy for changes between 1981 and 1986	0.250	0.437	0	1
$D3$	Dummy for changes between 1986 and 1991	0.250	0.437	0	1
$D4$	Dummy for changes between 1991 and 1996	0.250	0.437	0	1
RD/SD	R&D/sales (%)	1.458	1.214	0.178	4.814
$\Delta \ln K$	Changes in real net capital stock (total: %)	63.73	24.53	–16.54	138.84
$\Delta \ln Y$	Changes in real value added (%)	52.10	29.58	–31.15	109.17
$\Delta \ln E$	Changes in real net capital stock (equipment: %)	61.50	26.96	–33.96	139.26
$\Delta \ln(K/Y)$	Changes in capital-output ratio (% p)	11.63	31.53	–46.77	80.80
$\Delta \ln(E/Y)$	Changes in equipment-output ratio (% p)	9.40	33.38	–64.92	80.80

for manufacturing industries, we have no choice but to restrict the analysis to these industries. We try to make a consistent industry classification system across data and time periods, resulting in fourteen distinct industry groups.[8]

We use 1976, 1981, 1986, 1991, and 1996 data due to their availability. For the estimation of equation (1), we need constant values for each data set. Since no information was available for the deflator in each industry in each data set, we used the estimated constant values in each data set. We also use the sum of each estimated real values if we aggregate two or more industries into one.[9]

Table VI reports summary statistics for each set of data. In all industries, the average ratio of the R&D expenditure to sales was 1.458 per cent. The average growth rate of real net capital stock per year was 10.36 per cent, and that of real net equipment stock per year was 10.06 per cent. Hence most of the increases in capital stock were attributable to that of equipment stock. The average growth rate of real value added per year was 8.75 per cent, which is less than that of real net capital stock.

Table VII shows the estimated results of changes in employment and wage shares

[8] The resulting fourteen industry groups are: food products and beverages; textile, clothing, and leather; wood and wood products; paper, publishing, and printing; coke and refined petroleum; chemical and chemical products; non-metallic mineral products; basic metals; fabricated metal products; general machinery; electric and electronic products; motor vehicles and other transportation equipment; medical, precision, and optical instruments; and other manufacturing. Details upon request.

[9] In principle, we also have to deflate the R&D expenditure over sales by using appropriate deflators in each industry. Since the deflators for each industry's R&D expenditure and sales are not available, and the R&D expenditure over sales is a ratio variable, we do not deflate each variable separately (in effect, we assume the same deflator for numerator and denominator).

TABLE VII

REGRESSION RESULTS

Variables	A. Dependent Variable: Changes in Employment Share									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ln*RD*/*SD*				1.065	1.111				1.707*	1.763*
				(1.386)	(1.455)				(1.727)	(1.794)
$\Delta\ln(K/Y)$		0.016		0.020			0.024		0.040	
		(0.698)		(0.854)			(0.933)		(1.510)	
$\Delta\ln(E/Y)$			0.026		0.030			0.027		0.044
			(1.250)		(1.439)			(1.088)		(1.681)
D2	1.005	1.764	2.296	1.135	1.643	–0.192	0.939	1.122	0.132	0.287
	(0.595)	(0.973)	(1.306)	(0.624)	(0.915)	(0.106)	(0.431)	(0.516)	(0.060)	(0.132)
D3	4.959	5.087	5.150	4.523	4.560	5.753	5.834	5.806	4.052	3.939
	(2.198)	(2.282)	(2.326)	(2.131)	(2.156)	(3.176)	(3.213)	(3.209)	(1.967)	(1.917)
D4	–1.268	–1.098	–1.053	–1.806	–1.801	–2.911	–2.626	–2.640	–4.397	–4.507
	(0.590)	(0.508)	(0.486)	(0.820)	(0.810)	(1.445)	(1.287)	(1.303)	(1.955)	(2.012)
Constant	2.506	2.056	1.841	2.424	2.238	3.161	2.378	2.317	2.988	2.990
	(1.147)	(1.272)	(1.531)	(2.023)	(1.950)	(2.468)	(1.551)	(1.549)	(1.934)	(1.978)
R^2	0.135	0.139	0.147	0.155	0.164	0.293	0.305	0.309	0.344	0.351

Variables	B. Dependent Variable: Changes in Wage Share									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ln*RD*/*SD*				2.332	2.346				2.173	2.252
				(0.998)	(1.004)				(0.942)	(0.975)
$\Delta\ln(K/Y)$		0.123*		0.132*			0.070		0.091	
		(1.882)		(1.993)			(1.178)		(1.426)	
$\Delta\ln(E/Y)$			0.120*		0.128*			0.073		0.094
			(2.033)		(2.180)			(1.234)		(1.494)
D2	9.809	15.702	15.851	14.325	14.474	5.873	9.192	9.338	8.147	8.273
	(2.053)	(2.769)	(2.745)	(2.402)	(2.369)	(1.404)	(1.828)	(1.861)	(1.580)	(1.610)
D3	1.629	2.618	2.524	1.385	1.277	3.192	3.609	3.537	1.458	1.270
	(0.321)	(0.540)	(0.522)	(0.281)	(0.259)	(0.763)	(0.863)	(0.846)	(0.306)	(0.266)
D4	10.474	11.788	11.478	10.240	9.900	3.406	4.448	4.342	2.229	2.004
	(2.070)	(2.382)	(2.357)	(1.884)	(1.846)	(0.742)	(0.954)	(0.937)	(0.426)	(0.384)
Constant	–3.898	–7.388	–7.012	–6.582	–6.174	–1.142	–3.304	–3.234	–2.522	–2.388
	(1.088)	(1.823)	(1.806)	(1.586)	(1.544)	(0.386)	(0.852)	(0.963)	(0.706)	(0.681)
R^2	0.115	0.166	0.147	0.183	0.184	0.037	0.062	0.065	0.079	0.082

Notes:
1. Figures in parentheses are *t*-values.
2. Equations (1) to (5) were calculated using OLS with heteroscedasticity consistent covariance estimates, and equations (6) to (10) were calculated using WLS with weights given by an employment or wage share.
3. An asterisk denotes statistical significance at the 10 per cent level.

of white-collar workers. We consider five sets of explanatory variables. The first of the five specifications includes only three time dummy variables; the second includes the capital-output ratio, $\Delta\ln(K/Y)$; the third includes the equipment-output ratio, $\Delta\ln(E/Y)$; the fourth includes the capital-output ratio, $\Delta\ln(K/Y)$, and the R&D-sales ratio, $\ln(RD/SD)$; and the fifth includes $\Delta\ln(E/Y)$ and $\ln(RD/SD)$. We estimate the share equation by OLS with heteroscedasticity consistent variance estimates, and also by WLS with weights given by a share for each industry.

The estimation results show that as in Berman, Bound, and Griliches (1994), upskilling has been observed throughout the periods, but no acceleration as shown in Berman, Bound, and Griliches (1994) has been observed. In all the specifications, the estimated coefficients of the capital-output ratio, $\Delta\ln(K/Y)$, and the equipment-output ratio, $\Delta\ln(E/Y)$, are positive, and in some cases they are statistically significant. This might be interpreted as indicating the capital-skill complementarities also hold in Korea. The residuals from the specifications A(2), A(7), B(2), and B(7) can be interpreted as biased technological change.

What are the main causes of the technological change? To directly investigate the sources of technological change, Berman, Bound, and Grilliches (1994) considered investment in computers and expenditures on R&D, while Colecchia and Papaconstantinou (1996) took R&D intensity and the number of patents into account. In this study, we consider the ratio of R&D expenditure over sales. When we explicitly added the R&D-sales ratio as an explanatory variable, in every specification, the estimated coefficient is positive, and in specifications A(9) and A(10), it is statistically significant. This can be interpreted as a direct evidence of skill-biased technological change.

It is worthwhile to note that the two specifications on the dependent variables, i.e., the wage and employment share of white-collar workers, yield somewhat different coefficient estimates. This is contrary to Berman, Bound, and Griliches (1994), where these two specifications yielded similar results. When we use the wage share as a dependent variable, the absolute sizes of coefficient estimates of the capital-output and R&D-sales ratio are greater than when we use the employment share as a dependent variable. When we use the employment share as a dependent variable, the increase in demand for white-collar workers records the highest figure between 1986 and 1991. When we use the wage share as a dependent variable, it records the highest figure between 1981 and 1986. Since the wage and employment shares are both determined by demand and supply of white-collar workers, this brings to relief our need for further studies on not only demand for white-collar workers, but also their supply.

V. CONCLUSION AND LIMITATIONS

There are few studies that directly address the upskilling issues in developing countries. Since theoretical analyses of these issues can yield different results depending on the assumptions employed, upskilling in developing counties, and the factors of upskilling, if any, are rather empirical questions.

This study shows that upskilling that occurs in developed countries in terms of the ratio of the number of white-collar workers to that of blue-collar workers has also occurred in Korea, one of developing countries. Increasing demand for highly-skilled workers reflected in their employment and wage shares can be largely explained by “within industry” shifts, not by “between industry” shifts especially in the manufacturing industry. To further investigate the cause of these shifts, changes in white-collar shares are regressed on the capital-output and R&D-sales ratio. Estimated coefficients on the capital-output ratio are positive, suggesting capital-skill complementarities. The positive coefficient estimate of the R&D-sales ratio can be interpreted as a direct evidence of skill-biased technological change.

Korea can be regarded as one of developing countries, especially during the 1980s. This study shows that a developing country can also experience upskilling in the process of economic development. As shown in Katz (1999), Haskel and Slaughter (1998), and Johnson (1997), upskilling can result in more unequal distribution. To mitigate this problem, governments in developing countries should put more emphasis on supply of skilled labor, i.e., education.

Some points need further research. First of all, the acceleration of upskilling is not observed in Korea. This is in contrast to the general belief that the Korean industry has become more technology-oriented in recent years. In Korea, the wage differential between highly-educated and low-educated workers is getting smaller, while the wage differential between highly-skilled and low-skilled workers is getting larger. In other developed countries, the wage differential between highly- and low-educated and that between highly- and low-skilled workers seem to move in the same direction. This difference needs further research.

Korea’s case cannot be directly applied to other developing countries and its experience needs to be compared to those of other developing countries. Also, this study needs to be refined by using richer, more detailed, more accurate, and more consistent data sets.

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