Exploring Substitutability across Age Groups and the College-High School Wage Gap in Korea

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Abstract

This study starts from the fact that, in Korea, the gap between age groups in tertiary attainment is the largest in all OECD countries, and educational wage gaps have shown different trends by age groups over the past three decades. The purpose of this study is to examine how change in the age group-specific relative supply of labor, or aggregate relative supply of labor affects the college-high school wage gap for a given age group, using the model by Card and Lemieux (2001).

Overall results suggest that different age groups are imperfect substitutes and therefore improvement in productivity may require a combination of different age groups, including both younger and older workers. On the other hand, the results cannot refute the possibility that different education groups are perfectly substitutable in Korea. These findings are consistent with results for Japan which has a strong seniority system, but not for countries that do not. Looking at subgroups, imperfect substitution between different age groups is found for workers with high experience, especially in small firms. Also, imperfect substitution between different education groups is found in large firms. These findings suggest that age or experience are the main contributing factors in explaining the change in the college-high school wage gap for specific age groups, and have crucial implications for intergenerational coexistence.

JEL classification codes: I26; J21; J31

Keywords: Age; Experience; Imperfect substitution; Educational wage gap

1. Introduction

Korean society is well known for its enthusiasm for education. The majority of high school graduates pursue tertiary education, and the college enrollment rate increased from 30% to 80% between 1980 and 2010. One of the most remarkable trends in the Korean labor market is that the college-high school wage gap has not declined, remaining constant despite the steady increase in the relative supply of college-educated workers. Figure 1 shows how the college-high school wage

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gap and the college-high school relative supply of labor have changed between 1980 and 2012. The college-high school wage gap declined steadily, coupled with an increase in the relative supply of highly educated workers after the early 1980s, when the graduation quota system started[1]. However, the college-high school wage gap for workers has not declined but remained nearly constant since the mid-1990s, although the relative supply of highly educated workers has increased steadily due to institutional changes, including the relaxation of the requirements to establish new colleges.

Although the college-high school wage gap in Korea is relatively small compared to other developed countries[2], Korean society is very sensitive to discrimination stemming from educational attainment (i.e., judging people based not on their ability but on their educational background and connections to the "old boy network"). Reflecting Korean society's high expectations for educational equality, in December 2013, the Korean legislature adopted an anti-discrimination law for education, prohibiting discrimination based on differences in educational attainment.

There are two major economic explanations proposed to account for the change in the college-high school wage gap[3]. First, many studies argue that the college-high school wage gap has not declined despite continuous increases in the relative supply of highly educated workers because the relative demand for college-educated workers has outpaced growth in the relative supply of college-educated workers.[4] Regarding the rise in relative demand, there are disputes over whether it is driven by the rise in international trade or by skill-biased technology complementary to highly skilled workers[5].

Second, some studies point to the importance of labor supply as a contributing factor in the college-high school wage gap[6]. This supply side approach has crucial implications for education and labor market policy. This is because the supply factor, which increases access to higher education, puts downward pressure on the wage gap, as well as contributing human capital development. In Korea, where the college enrollment rate has skyrocketed in the last 30 years, the gap between age groups in tertiary attainment is extremely large. In most OECD countries, younger age groups have a higher rate of tertiary attainment than older age groups by an average of 15 percentage points, but in Korea, the gap is 51 percentage points, the largest in all OECD countries[7]. Thus, it is clear that the effect of the relative labor supply on the college-high school wage gap can differ markedly by age groups in Korea.

If different age groups are perfectly substitutable, changes in the age group-specific relative supply of labor will not affect the age profile of the college-high school wage gap. This is because there is

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1 This system was intended to make it easy to get into college and hard to graduate by setting the "graduation quota" instead of the "entrance quota". However, as most students who entered college did graduate, the relative supply of college-educated labor increased.

2 See Education at a Glance 2013 (OECD): The relative earning for the college-educated workers in Korea is 147, and it is lower than the U.S. (177), U.K. (157), Germany (164), Japan (148), and OECD average (157).

3 Beyond the demand and supply side explanations, some studies suggest alternative factors that may contribute to educational wage gaps such as declining unionization (Card and DiNardo, 2002), the increased labor force participation of women, and immigration (Topel, 1997).

4 Bound and Johnson (1992), Autor, Katz and Krueger (1998), and Choi and Cho (2013).

5 Card and DiNardo (2002), Autor, Katz and Kearney (2006), and Choi and Cho (2013).

6 Katz and Murphy (1992), Topel (1997), Card and Lemieux (2001), Audra and Chris (2012), Kawaguchi (2013), and Jeong et al. (2015).

7 See Education at a Glance 2013 (OECD).

no need to distinguish between younger and older workers (homogeneous labor) in the combination of production factors.[8] Thus, the change in the college-high school wage gap should show the same trends across age groups. On the other hand, if different age groups are perfectly heterogeneous, the effect of higher education on the college-high school wage gap will show different trends across age groups, and the effect will be driven mainly by younger age groups.

Conventional models of educational wage gaps assumed perfect substitution across age groups.[9] Card and Lemieux (2001), however, analyze the college-high school wage gap across age groups, considering younger and older workers, using a model in which different age groups with the same educational attainment are imperfect substitutes. They find that the college-high school wage gaps for older workers have remained constant, while the gaps for younger workers increased sharply after 1973. Also, they emphasize that the reason changes in college-high school wage gaps differ by age groups is due to the change in the age group-specific relative supply of college-educated labor, resulting from imperfect substitutability across age groups.[10]

Indeed, in Korea, the college-high school wage gaps of different age groups have shown different trends over the past three decades[11]. Figure 2 plots college-high school relative labor supplies and wage gaps by age groups from 1980 to 2012, showing that the college-high school wage gaps for older workers have declined substantially since the 1980s, while the gaps for younger workers have not changed significantly since the early 1990s.

In Korea, only a few studies have examined the educational wage gap in relation to age groups or cohorts; most studies looked at all ages and the role of increased demand. Moreover, few existing studies have analyzed the magnitude of elasticity of substitution across age groups[12]. To address these issues, this study focuses on the supply side of the college-high school wage gap rather than the demand side. It examines how the change of the age group-specific relative supply of labor affects the change in the college-high school wage gap for a given age group, using Card and Lemieux (2001)'s model, which assigns a key role to imperfect substitutability across age groups. The degrees of the substitutability across age groups developed in this study have implications for the crowding-out effect in employment, especially as it relates to the extension of the mandatory retirement age for older workers.

This paper proceeds as follows: Section 1 outlines the conceptual framework, and Section 2 presents the model and estimation method that guides our analysis. Section 3 describes the data set used in this empirical work. Section 4 presents the results of the estimation, and Section 5 concludes the paper.

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[8] However, the problem of production costs will still exist.

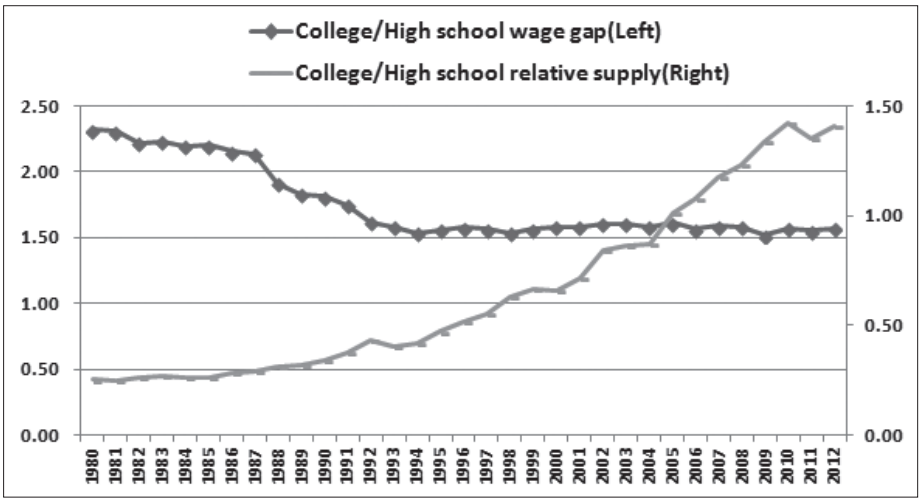
[9] Freeman (1976), Katz and Murphy (1992), and Jeong (2004).

[10] In a recent study, Jeong et al. (2015) demonstrate that the changing relative supply of experience (years of worked) can account for the differential movements of the college premium across age groups.

[11] There is a clear consensus in the economic literature that the educational wage gap shows different trends by age groups. See Card and Lemieux (2001) for the cases in the U.S., U.K., and Canada, and Ohtake (2006) for Japan.

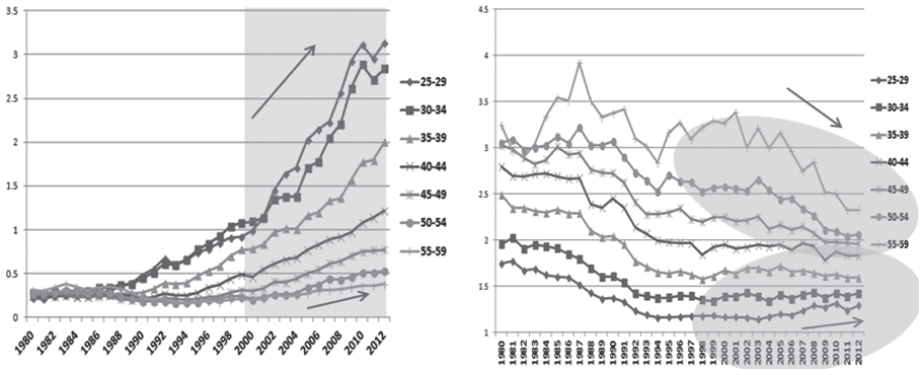
[12] As noted in Choi (2013), the estimated elasticity of substitution between age and education groups is about 10 and 2, respectively.

Figure 1: The College-High School Wage Gap and Relative Supply over Time



Source: Ministry of Employment and Labor, Survey on Labor Conditions by Type of Employment (workplaces with ten or more employees).

Figure 2: The College-High School Relative Supply (left) and Wage Gap (right) by Age Groups



Source: Ministry of Employment and Labor, Survey on Labor Conditions by Type of Employment (workplaces with ten or more employees).

2. Conceptual Framework

Much previous research on the return to schooling was conducted under the assumption that different age groups with the same educational attainment are perfectly substitutable.[13] In this case, the aggregate supply of each category of education, high school or college, can be found by simply summing the total number of workers across all age groups. However, the assumption of perfect substitution across different age groups may not represent the reality of the labor market, especially in

[13] Freeman (1976), Katz and Murphy (1992), and Jeong (2004).

countries with a strong seniority system.

This section contains description of the imperfect substitution model of Card and Lemieux (2001) being used as a theoretical framework. In their influential paper, Card and Lemieux (2001) used a model which assumes that different age groups with the same educational attainment are imperfectly substitutable. In order to relax the hypothesis of perfect substitution across age groups, aggregate output is represented by two CES sub-aggregates of high school labor ($\mathrm{H_t}$) and college labor (Ct).

(1) $$H_t = \left[\sum_j (\alpha_j H_{jt}^{\mu})\right]^{1/\mu},$$

and

(2) $$C_t = \left[\sum_j (\beta_j C_{jt}^{\mu})\right]^{1/\mu},$$

where $-\infty < \mu \leq 1$ is determined by the elasticity of substitution (σ_A) across age groups j with the same degree of education, i.e., ($\mu = 1 - 1/\sigma_A$). α_j and β_j denote relative efficiency parameters (assumed to be constant over time). When different age groups are perfectly substitutable, μ is equal to 1, and total labor input (H_t and C_t) is simply a weighted sum of different age groups j of labor supply. Although μ could theoretically be different across education groups, this study assumes there is no difference to simplify the model. This possibility will be discussed in detail in section 5.

This study assumes that the aggregate production function can also be expressed as a CES production function:

(3) $$y_t = (\kappa_{ht} H_t^{\tau} + \kappa_{ct} C_t^{\tau})^{1/\tau},$$

where $-\infty < \tau \leq 1$ is dependent on the elasticity of substitution between different education groups (σ_E), i.e.,. ($\tau = 1 - 1/\sigma_{\mathrm{E}}$). y_t denotes the aggregate output in period t and κ_{ht} and κ_{ct} denote the technological efficiency parameters of high school labor (H_t) and college labor (C_t).

The marginal product of high school-educated workers divided by age group j, can be expressed in the following form, equation (4), and decomposed into the aggregate supply of labor and age group j's supply of labor.

(4) $$\frac{\partial y_t}{\partial H_{jt}} = \frac{\partial y_t}{\partial H_t} \times \frac{\partial H_t}{\partial H_{jt}}$$
$$= \left(\kappa_{ht} H_t^{\tau-1} \pi_{\mathrm{t}} \times \alpha_j H_{jt}^{\mu-1} H_t^{1-\mu}\right)$$
$$= \left(\kappa_{ht} H_t^{\tau-\mu} \pi_{\mathrm{t}} \times \alpha_j H_{jt}^{\mu-1}\right) \qquad \text{where} \quad \pi_t = (\kappa_{ht} H_t^{\tau} + \kappa_{ct} C_t^{\tau})^{\frac{1}{\tau}-1}$$

In the same way, the marginal product of college-educated workers divided by age group j, can be obtained in the following form.

(5) $$\frac{\partial y_t}{\partial C_t} = \left(\kappa_{ct} C_t^{\tau-\mu} \pi_{\mathrm{t}} \times \beta_{\mathrm{j}} C_{jt}^{\mu-1}\right)$$

For different skill groups to be utilized efficiently, relative wages ($\mathrm{w_{jt}^c}/\mathrm{w_{jt}^h}$) should be equal to relative marginal products $(\partial y_t/\partial C_{jt})/(\partial y_t/\partial H_{jt})$. Under these conditions, equations (4) and (5) can be reduced to equation (6):

$$(6) \qquad \log\left(\frac{w_{jt}^{c}}{w_{jt}^{h}}\right) = \log\left(\frac{\partial \mathrm{y_t}/\partial \mathrm{C_{jt}}}{\partial \mathrm{y_t}/\partial \mathrm{H_{jt}}}\right) = \log\left(\frac{\kappa_{ct}}{\kappa_{ht}}\right) + (\tau-\mu)\log\left(\frac{C_t}{H_t}\right) + \log\left(\frac{\beta_j}{\alpha_j}\right) + (\mu-1)\,log\left(\frac{C_{jt}}{H_{jt}}\right)$$

Given the relative supply of labor, equation (6) can be simplified to equation (7a) to provide a model for the college-high school wage gap of workers in age group j in year t:

$$(7a) \qquad \log\left(\frac{w_{jt}^{c}}{w_{jt}^{h}}\right) = \log\left(\frac{\kappa_{ct}}{\kappa_{ht}}\right) + \log\left(\frac{\beta_j}{\alpha_j}\right) + \left[\left(\frac{1}{\sigma_A}\right) - \left(\frac{1}{\sigma_E}\right)\right]\log\left(\frac{C_t}{H_t}\right) - \left(\frac{1}{\sigma_A}\right) log\left(\frac{C_{jt}}{H_{jt}}\right) + \mathrm{e_{jt}}$$

Under this model, if different age groups are perfect substitutes, i.e. $\left(\sigma_{\mathrm{A}} = +\infty\right)$, $1/\sigma_{\mathrm{A}}$ equals 0 and the college-high school wage gap for a given age group is determined only by the aggregate relative supply of labor $(\mathrm{C_t}/\mathrm{H_t})$ and the relative technology shock $(\log(\kappa_{ct}/\kappa_{ht}))$. However, if different age groups are imperfect substitutes (i.e., $1/\sigma_{\mathrm{A}} > 0$), the college-high school wage gap for a given age group also depends on the age group-specific relative supply of labor $(\mathrm{C_{jt}}/\mathrm{H_{jt}})$. Thus, the change in age group-specific relative supply would result in a shift in the age profile of the college-high school wage gap, dependent on the size of $1/\sigma_{\mathrm{A}}$.

Alternatively, equation (7a) can be rearranged to equation (7b):

$$(7b) \qquad \log\left(\frac{w_{jt}^{c}}{w_{jt}^{h}}\right) = \log\left(\frac{\kappa_{ct}}{\kappa_{ht}}\right) + \log\left(\frac{\beta_j}{\alpha_j}\right) - \left(\frac{1}{\sigma_E}\right)\log\left(\frac{C_t}{H_t}\right) - \left(\frac{1}{\sigma_A}\right)\left[log\left(\frac{C_{jt}}{H_{jt}}\right) - \log\left(\frac{C_t}{H_t}\right)\right] + \mathrm{e_{jt}}$$

In this case, if $\log(\mathrm{C_{jt}}/\mathrm{H_{jt}}) - \log(\mathrm{C_t}/\mathrm{H_t})$ remains the same over time, the cohort effects can be ignored even though different age groups are not perfect substitutes (i.e., $1/\sigma_{\mathrm{A}} > 0$). However, if $\log(\mathrm{C_{jt}}/\mathrm{H_{jt}}) - \log(\mathrm{C_t}/\mathrm{H_t})$ changes over time, the college-high school wage gap for a given age group will have cohort effects that vary by age and year. Supposing that the log relative supply for a given age group j in year t $(\log(\mathrm{C_{jt}}/\mathrm{H_{jt}}))$ is comprised of a cohort effect for the group $(\theta_{\mathrm{t-j}})$ and an age effect (η_j), i.e., $\log(\mathrm{C_{jt}}/\mathrm{H_{jt}}) = \theta_{\mathrm{t-j}} + \eta_j$, Equation (7b) can be represented in the following form, equation (8).

$$(8) \qquad \log\left(\frac{w_{jt}^{c}}{w_{jt}^{h}}\right) = \log\left(\frac{\kappa_{ct}}{\kappa_{ht}}\right) + \log\left(\frac{\beta_j}{\alpha_j}\right) - \left(\frac{1}{\sigma_A}\right)\eta_{\mathrm{j}} + \left[\left(\frac{1}{\sigma_A}\right) - \left(\frac{1}{\sigma_E}\right)\right]\log\left(\frac{C_t}{H_t}\right) - \left(\frac{1}{\sigma_A}\right)\theta_{\mathrm{t-j}} + \mathrm{e_{jt}}$$

This implies that the college-high school wage gap for a given age group j in year t can be decomposed into year effects that are constant over age groups $(\log(\kappa_{ct}/\kappa_{ht}) + [(1/\sigma_A)\text{-}(1/\sigma_E)]\log(C_t/H_t))$, age effects that are constant across years $(\log(\beta_{\mathrm{j}}/\alpha_{\mathrm{j}}) - (1/\sigma_A)\eta_{\mathrm{j}})$, and cohort effects $((1/\sigma_A)\theta_{\mathrm{t-j}})$.

3. Estimation Method

The main goal of this study is to determine the effect of age group-specific relative supplies and aggregate relative supplies on age group-specific returns to college – that is, to estimate σ_A and σ_E in equation (7a) or (7b). However, the difficulty of using equation (7a) or (7b) to estimate σ_A and σ_E is that the aggregate relative supply $(\mathrm{C_t}/\mathrm{H_t})$ depends on the elasticity of substitution across age groups

(σ_A). To resolve this issue, this study employs a simple two-step estimation procedure to identify both σ_A and σ_E.

First, a regression of age group-specific college wage gaps on age effects (λ_j), year effects (δ_j), and age group specific-relative supplies (C_{jt}/H_{jt}) is used to estimate σ_A in equation (9). The age effects, λ_j, contain the relative productivity effect log (β_j/α_j), and the year effects, δ_j, contain the relative technology shock log (κ_{ct}/κ_{ht}).

$$\log\left(\frac{w_{jt}^{c}}{w_{jt}^{h}}\right) = \lambda_j + \delta_j - (1/\sigma_A)\log(C_{jt}/H_{jt}) + e_{jt} \quad (9)$$

Relative wages of high school and college workers in equations (4) and (5) can be rearranged as in equations (10a) and (10b) and then finally as in equation (11)[14].

$$\log(w_{jt}^{h}) + (1/\sigma_A)H_{jt} = \log(\kappa_{ht}H_t^{\tau-\mu}\pi_t) + \log(\alpha_j) \text{ and} \quad (10a)$$

$$\log(w_{jt}^{c}) + (1/\sigma_A)C_{jt} = \log(\kappa_{ct}C_t^{\tau-\mu}\pi_t) + \log(\beta_j) \text{ for all values of } j \text{ and } t. \quad (10b)$$

$$\log\left(\frac{w_{jt}^{c}}{w_{jt}^{h}}\right) + \left(\frac{1}{\sigma_A}\right)\log\left(\frac{C_t}{H_t}\right) = b_1 * trend + b_2\log\left(\frac{\beta_j}{\alpha_j}\right) - \left(\frac{1}{\sigma_E}\right)\log\left(\frac{C_t}{H_t}\right) - \left(\frac{1}{\sigma_A}\right)log\left(\frac{C_{jt}}{H_{jt}}\right) + e_{jt} \quad (11)$$

Second, the estimate of $1/\sigma_A$ from the first stage (equation (9)) can be substituted into the left side of equation (11). Through a regression of the left side of equation (11) on trend, age effects, the aggregate relative supply, and the age group-specific relative supplies, an estimate of σ_A and σ_E can be calculated. This will produce a second estimate of $1/\sigma_A$, which is expected to be similar to the estimate calculated in the first stage. According to the this study's model, a non-zero value of $1/\sigma_A$, indicating imperfect substitutability of different age groups of similarly educated workers, would be expected. If a statistically significant negative value is obtained for the effect of age group-specific relative supply ($-1/\sigma_A < 0$), then the elasticity of substitution across age groups (σ_A) can be calculated.

4. Data

This study uses the Survey on Labor Conditions by Type of Employment conducted by the Ministry of Employment and Labor in Korea. This is an annual survey covering a sample of 32,284 workplaces with one or more employees. The survey provides earnings, hours worked, employment estimates at each job in a reference period, as well as information on age, gender, education, occupation, industry, and tenure[15]. For the main analysis, this study focuses on hourly earnings at full-time jobs held by workers, both male and female, aged 25–59 (7 age groups) in each year from 1980 to 2012.

Average hourly earnings are calculated by dividing total monthly earnings by hours worked during

[14] Assuming that the relative productivity term log (κ_{ct}/κ_{ht}) can be represented as a linear trend is consistent with the existing literature.

[15] For more details, see http://www.moel.go.kr/english/pas/pasMOEL.jsp

the month. The college-high school wage gaps are obtained by dividing the earnings of workers with a college education by the earnings of workers with a high school education or less. In the same way, the college-high school relative supplies are obtained by dividing the number of workers with a college education by the number of workers with a high school education or less.

5. Results

5.1. Main Results: Estimated Results for the College-High School Wage Gap

First, we turn to the estimation of the effects of the age group-specific relative supply of labor, or aggregate relative supply of labor on the college wage premium. In this section, regressions of the age group-specific educational wage gap on the age group-specific relative supply, the aggregate supply, age effects and year effects are used. Table 1 presents estimates from a set of models (columns 1-5) for our two-step estimation procedure. Columns (1) to (4) of Table 1 show the estimation results for models considering workers with a college education and a high school education. Column (5) shows the estimated results for the model including workers with a college education and a high school education or less.

In the first specification (column 1), dummies for 5-year intervals (5-year dummy variables) are used as year effects. The estimated effect of the age group-specific relative supply is negative and highly significant, but the 5-year dummies show no consistent pattern. The second specification (column 2) takes out the 5-year dummies and replaces them with a linear trend. The estimated effect of the age group-specific relative supply index is still negative and highly significant, which suggests that different age groups are imperfect substitutes. However, the trend variable has no significant effect in the first stage. The third specification (column 3) then replaces the trend variable with the value (0.012) derived from a previous study (Card and Lemieux, 2001) in lieu of estimating the trend variable. As expected, placing an exogenous figure into the model does not fit well. The estimates (-0.043) of the age group-specific relative supply from the second stage procedure are very different from the first stage estimates (-0.036).

The fourth specification (column 4) supposes a model that has a quadratic term as well as the linear term. This is considered because the model with the linear trend increasing over time may have a multicollinearity problem due to the college-high school relative supply increasing over time; that is, there may be multicollinearity between the aggregate supply and the linear time trend. The estimated results in column (4) show that the coefficients of trend variables switch from negative to positive at a certain point, and the estimates are highly significant. Moreover, this specification seems a better fit. The adjusted R^2 is about 90%. The estimated effect of the age group-specific relative supply index, $1/\sigma_A$, is statistically significant and negative (approximately -0.12). This estimate implies that different age groups are imperfect substitutes, and the elasticity of substitution between different age groups is in the range of 8-9.[16] It is also interesting to note that the estimate (-0.118) of $1/\sigma_A$ from

[16] This result is similar to the finding of Choi (2013), which estimate the elasticity of substitution across age groups to be around 10.

Table 1. Estimated Results for the College-High School Wage gap: Overall Results

Dependent Variable:C-H Wage gap	(1)	(2)		(3)		(4)		(5)	
		1 stage	2 stage	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage
Age group -specific relative supply	- 0.088*** (0.012)	-0.079*** (0.013)	-0.102*** (0.014)	-0.336*** (0.040)	-0.043* (0.022)	-0.117*** (0.012)	-0.118*** (0.012)	-0.050*** (0.014)	-0.050*** (0.014)
Aggregate supply index			0.384*** (0.052)		-0.370*** (0.026)		0.207** (0.072)		0.038 (0.071)
Trend		-0.0001 (0.0002)	-0.005*** (0.001)	-	-	-0.007*** (0.001)	-0.006*** (0.001)	-0.010*** (0.001)	-0.010*** (0.001)
Trend^2						0.0002*** (0.000)	0.0002*** (0.000)	0.0002*** (0.000)	0.0002*** (0.000)
year effects									
1987	0.030** (0.012)								
1992	-0.029** (0.012)								
1997	-0.027** (0.012)								
2002	-0.000 (0.012)								
2007	0.024** (0.012)								
2012	0.009 (0.012)								
Age effects									
age30-34	0.055*** (0.008)	0.055*** (0.008)	0.079*** (0.007)	0.066** (0.028)	0.053*** (0.013)	0.056*** (0.007)	0.056*** (0.007)	0.064*** (0.007)	0.064*** (0.007)
age35-39	0.108*** (0.008)	0.108*** (0.008)	0.116*** (0.007)	0.098*** (0.028)	0.109*** (0.013)	0.107*** (0.007)	0.107*** (0.007)	0.138*** (0.008)	0.138*** (0.008)
age40-44	0.145*** (0.008)	0.146*** (0.008)	0.141*** (0.007)	0.119*** (0.028)	0.149*** (0.013)	0.142*** (0.007)	0.142*** (0.007)	0.198*** (0.008)	0.198*** (0.008)
age45-49	0.171*** (0.008)	0.172*** (0.008)	0.167*** (0.007)	0.134*** (0.028)	0.178*** (0.014)	0.167*** (0.007)	0.166*** (0.007)	0.240*** (0.009)	0.240*** (0.009)
age50-54	0.197*** (0.008)	0.199*** (0.008)	0.228*** (0.007)	0.159*** (0.028)	0.205*** (0.014)	0.193*** (0.007)	0.193*** (0.007)	0.280*** (0.010)	0.280*** (0.010)
age55-59	0.257*** (0.008)	0.259*** (0.008)	0.228*** (0.007)	0.223*** (0.028)	0.264*** (0.014)	0.253*** (0.007)	0.253*** (0.007)	0.344*** (0.010)	0.344*** (0.010)
Obs	231	231	231	231	231	231	231	231	231
F-value	147.3***	219.0***	208.2***	29.8***	112.3***	257.6***	237.8***	512.8***	430.3***
Adjusted R^2	0.892	0.884	0.878	0.467	0.795	0.909	0.912	0.952	0.949

Notes: Standard errors in parentheses. Significance level: * 10%, * 5%, * 1%.
In dummy variables for year and age effects, the reference categories are 'year 1982' and 'age group 25-29', respectively.

the second stage procedure is very close to the first stage estimate (-0.117). On the other hand, the estimated effect of the aggregate supply variable, $1/\sigma_E$, is statistically significant and positive (0.207), which is inconsistent with the hypothesis of this model.

The final specification (column 5) includes workers with less than a high school education (e.g. high school dropouts). Although the estimated effects of the age group-specific relative supply, $1/\sigma_A$, are smaller than when the narrower definition of workers with high school education is used (see column 4), this is still statistically significant. The estimated effect (-0.05) implies that the elasticity

of substitution between different age groups goes up to 20, which is relatively high. In addition, the estimated effect of the aggregate supply variable, $1/\sigma_E$, has a statistically insignificant and positive coefficient, which means that this study cannot refute the possibility of perfect substitution between education groups in the combination of production factors.

To summarize our findings, the model (column 5) including the quadratic trend and workers with less than a high school education produces results that are not only consistent with the theory but also a better model fit. The findings of this study provide definite evidence that different age groups (younger or older workers) are imperfect substitutes, consistent with results from Japan, the United States, the United Kingdom and Canada. Although the degree of elasticity of substitution is much larger in Korea than in these countries, it is still far from infinite, indicating imperfect substitution across age groups. On the other hand, education groups were found to be perfectly substitutable, which is similar to findings for Japan, but not to those of other countries (Card and Lemieux 2001; Ohtake 2006).

5.2. Can Differences in Work Experience Explain the Imperfect Substitutability between Different Age Groups?[17]

What do the above findings of imperfect substitutability between different age groups and perfect substitutability between different educational groups mean? First, the imperfect substitutability between different age groups suggests that workers in different age groups may have different marginal productivity and cannot be perfectly substituted, i.e. heterogeneous labor. In this case, productivity can be improved by combining different age groups, including both younger and older age groups. Second, perfect substitutability between different education groups likely occurs because despite differing marginal productivity, workers from lower education groups can be perfectly substituted for higher education groups by increasing the labor inputs.

In many previous studies[18], the elasticity of substitution across age and education groups is assumed to be the same for all work experience groups. However, in labor markets with strong seniority wage systems like Korea and Japan, productivity differentials which result from differences in experience, not education, may contribute to imperfect substitutability between different age groups. To determine the validity of this assumption, this study has taken further steps to examine how elasticity of substitution across age groups varies with work experience.

The results of this analysis are shown in Table 2. As seen in the top row, the estimated effect of the age group-specific relative supply is significant and negative for workers with 5 years work experience or more. That is, workers with relatively high experience, unlike those with low experience, are imperfectly substitutable across different age groups. However, for the elasticity of substitution between different education groups, except in the 3-5 years experience groups, the results are inconsistent with the theory of this model and perfect substitutability cannot be refuted.

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[17] All results in this section are limited to workers with a college education and those with a high school education or less.

[18] Katz and Murphy (1992), Card and Lemieux (2001).

Table 2. Estimated Results for the College-High School Wage Gap by Work Experience

Dependent Variable: C-H Wage gap	Years of Work Experience									
	Less than 1 year		1-3 years		3-5 years		5-10 years		10 years +	
	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage
Age group -specific relative supply	0.014	0.006	-0.024	-0.020	0.013	0.026	-0.040***	-0.037***	-0.032***	-0.040***
	(0.025)	(0.025)	(0.022)	(0.023)	(0.018)	(0.019)	(0.012)	(0.013)	(0.011)	(0.011)
Aggregate supply index		0.236**		-0.053		-0.205***		-0.032		0.268***
		(0.106)		(0.100)		(0.075)		(0.051)		(0.051)
Trend	-0.018***	-0.025***	-0.013***	-0.011***	-0.009***	-0.004	-0.007***	-0.005***	-0.007***	-0.005***
	(0.002)	(0.004)	(0.002)	(0.004)	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
Trend^2	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Obs	231	231	231	231	231	231	231	231	231	231
F-value	147.9***	139.9***	179.4***	154.3***	185.5***	177.0***	442.1***	377.3***	405.1***	379.2***
Adjusted R^2	0.852	0.858	0.875	0.87	0.878	0.884	0.945	0.942	0.941	0.943

Notes: Standard errors in parentheses. Significance level: * 10%, * 5%, * 1%.

5.3. Estimation of College-High School Wage Gaps by Firm Size

In the Card and Lemieux (2001) model, the elasticity of substitution across age and education groups is assumed to be the same for small and large firms. However, differences in elasticity of substitution across age and education groups may be associated with firm-specific components such as firm size. To investigate this possibility, this section analyzes the college-high school wage gap with respect to firm size.

Table 3 summarizes the estimation results of the college-high school wage gap by firm size, considering workers with a college education and those with a high school education or less. As shown in the top row, the estimated effect of the age group-specific relative supply is significant and negative for both small and large firms. The estimated value is -0.04 for small firms and –0.05 for large firms. This suggests that different age groups are imperfectly substitutable and that firm size does not strongly affect the degree of elasticity of substitution across age groups (σ_A)[19]. However, in large firms, the estimated coefficient of the aggregate supply is significant and negative, suggesting that different education groups are imperfectly substitutable. While, in small and medium firms, it is significant and positive, which is incompatible with the theory and does not enable us to draw any conclusions.

Next, the same analysis is repeated with workers divided by years of experience to determine the effect of work experience on the elasticity of substitution across age and education groups in different size firms (Table 4). The results show that in small and medium firms (panel A), different age groups

[19] In the estimation results for the college-high school wage gap between workers with a college education and those with a high school education, the estimated coefficient of the age group-specific relative supply is approximately –0.11 for small firms and –0.08 for large firms, suggesting that the elasticity of substitution between different age groups is slightly greater in large firms than in small firms.

Table 3. Estimated Results for the College-High School Wage Gap by Firm Size

Dependent Variable: C-H Wage gap	Small and Medium firms (10~299 employees)		Large firms (300 or more employees)	
	1 stage	2 stage	1 stage	2 stage
Age group-specific relative supply	-0.045*** (0.014)	-0.050*** (0.014)	-0.047*** (0.016)	-0.040** (0.016)
Aggregate supply index		0.154** (0.057)		-0.198** (0.071)
Trend	-0.010*** (0.001)	-0.011*** (0.001)	-0.011*** (0.001)	-0.005** (0.002)
Trend^2	0.0002*** (0.000)	0.000* (0.000)	0.0001*** (0.000)	0.0002*** (0.000)
Age effects				
age30-34	0.069*** (0.008)	0.069*** (0.008)	0.050*** (0.009)	0.050*** (0.009)
age35-39	0.146*** (0.008)	0.145*** (0.008)	0.117*** (0.009)	0.118*** (0.009)
age40-44	0.212*** (0.009)	0.210*** (0.009)	0.168*** (0.010)	0.170*** (0.010)
age45-49	0.254*** (0.009)	0.252*** (0.009)	0.215*** (0.011)	0.218*** (0.011)
age50-54	0.291*** (0.010)	0.289*** (0.010)	0.263*** (0.012)	0.267*** (0.012)
age55-59	0.335*** (0.010)	0.333*** (0.010)	0.359*** (0.011)	0.362*** (0.011)
Obs	231	231	231	231
F-value	448.91***	388.47***	397.54***	342.59***
Adjusted R^2	0.946	0.944	0.940	0.937

Notes: Standard errors in parentheses. Significance level: * 10%, * 5%, * 1%.

are imperfectly substitutable only for workers with 10 or more years of experience (i.e., highly experienced), while in large firms (panel B), imperfect substitutability across age groups occurs for less-experienced workers with 1-10 years of experience. These findings suggest that experience has a

Table 4. Estimated Results for the College-High School Wage Gap by Firm Size*Work Experience

Panel A: Small and Medium Firms (10-299 employees)

Dependent Variable: C-H Wage gap	Years of Work Experience									
	less than 1 year		1-3 years		3-5 years		5-10 years		10 years +	
	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage
Age group - specific relative supply	0.033	0.002	-0.024	-0.033	0.023	0.028	-0.006	-0.008	-0.029**	-0.036***
	(0.027)	(0.028)	(0.021)	(0.131)	(0.019)	(0.021)	(0.012)	(0.013)	(0.012)	(0.012)
Aggregate supply index		0.313***		0.131		-0.072		0.024		0.198***
		(0.107)		(0.103)		(0.073)		(0.042)		(0.051)
Obs	231	231	231	231	231	231	231	231	231	231
F-value	117.3***	118.3***	165.8***	142.5***	145.7***	138.7***	328.8***	291.2***	265.9***	244.4***
Adjusted R^2	0.8198	0.8361	0.8658	0.8602	0.8499	0.8569	0.9277	0.9266	0.9127	0.9144

Panel B: Large Firms (300 or more employees)

Dependent Variable: C-H Wage gap	Years of Work Experience									
	less than 1 year		1-3 years		3-5 years		5-10 years		10 years +	
	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage	1 stage	2 stage
Age group -specific relative supply	-0.027	-0.027	-0.066***	-0.052**	-0.070***	-0.069***	-0.096***	-0.092***	0.014	0.013
	(0.022)	(0.023)	(0.022)	(0.023)	(0.020)	(0.020)	(0.018)	(0.018)	(0.013)	(0.013)
Aggregate supply index		0.028		-0.123*		0.057		-0.050		0.029
		(0.063)		(0.070)		(0.066)		(0.082)		(0.065)
Obs	231	231	231	231	231	231	231	231	231	231
F-value	104.0***	89.6***	167.3***	146.2***	203. 4***	174.5***	324.5***	284.1***	392.6***	360.6***
Adjusted R^2	0.8012	0.7939	0.8668	0.8632	0.8879	0.883	0.9268	0.9249	0.9392	0.9404

Notes: Standard errors in parentheses. Significance level: * 10%, * 5%, * 1%.

greater effect on imperfect substitutability across age groups in small firms than large firms.

5.4. Allowing for Differences in the Elasticity of Substitution by Education Groups

In equations (1) and (2), μ, a function of the elasticity of substitution across age groups (σ_A), was assumed to be the same for college and high school graduates. In principle, however, μ could be different for the two education groups. In light of this, we now relax this assumption. The elasticity of substitution between age groups, σ_A, is separated into σ_{AH} for high school graduates and σ_{AC} for college graduates, and the wage determination equation (7a), which indicates the condition that relative wages are equal to relative marginal products, can be decomposed to

$$\text{(12a)} \quad \log(w_{jt}^h) = \log(\kappa_{ht}) + \log(\alpha_j) + \left[\left(\frac{1}{\sigma_{AH}}\right) - \left(\frac{1}{\sigma_E}\right)\right]\log(H_t^*) - \left(\frac{1}{\sigma_{AH}}\right)\log(H_{jt}) + e_{jt}^h$$

and

$$\text{(12b)} \quad \log(w_{jt}^c) = \log(\kappa_{ct}) + \log(\beta_j) + \left[\left(\frac{1}{\sigma_{AC}}\right) - \left(\frac{1}{\sigma_E}\right)\right]\log(C_t^*) - \left(\frac{1}{\sigma_{AC}}\right)\log(C_{jt}) + e_{jt}^c,$$

Columns (1) and (3) of Table 5 summarize the estimation results for educational wage functions considering workers with a college education and a high school education. As shown in the top row, the estimated effect of the age group-specific relative supply is significant and negative for both workers with a high school education (column 1) and those with a college education (column 3). The estimated coefficient of the age group-specific relative supply is –0.653 and -1.018, respectively, resulting in an estimated elasticity of substitution across age groups (σ_A) of 1.53 and 0.98, respectively.

In column (2) of Table 5, the same set of analyses is repeated with workers with less than a high school education included. The signs on almost all of the estimates are unchanged, but the magnitude of the elasticity becomes larger for workers with less than high school education. The estimated coefficient of the age group-specific relative supply is -0.306, resulting in an estimated elasticity of

Table 5. Estimated Results for Educational Wage Functions: Allowing for Differences in the Elasticity of Substitution by Education Groups.

Dependent Variable: Hourly wage	(1) Workers with high school education	(2) Workers with high school education or less	(3) Workers with college education
Age group-specific relative supply	-0.653*** (0.046)	-0.306*** (0.045)	-1.018*** (0.061)
Aggregate supply index	0.565*** (0.040)	0.390*** (0.044)	0.780*** (0.058)
Trend	0.024*** (0.001)	0.036*** (0.001)	0.007** (0.002)
Age effects			
age30-34	0.085*** (0.013)	0.068*** (0.016)	0.136*** (0.010)
age35-39	0.124*** (0.014)	0.078*** (0.017)	0.202*** (0.013)
age40-44	0.137*** (0.015)	0.057*** (0.019)	0.224*** (0.020)
age45-49	0.135*** (0.016)	0.040* (0.021)	0.216*** (0.029)
age50-54	0.117*** (0.019)	0.020 (0.025)	0.190*** (0.038)
age55-59	0.032 (0.025)	-0.029 (0.031)	0.119** (0.052)
Obs	231	231	231
F-value	961.39***	805.05***	1885.92***
Adjusted R^2	0.974	0.969	0.987

Notes: Standard errors in parentheses. Significance level: * 10%, * 5%, * 1%.
In dummy variables for age effects, the reference category is 'age group 25-29'.

substitution across age groups (σ_A) of 3.27. To sum up, the results in Table 5 suggest that different age groups are imperfectly substitutable, and that the elasticity of substitution between different age groups is greater in workers with a high school education than in workers with a college education. As expected, when including workers with less than a high school education in the model, the elasticity of substitution increases, from 1.53 to 3.27.

5.5. Estimation Assuming Perfect Substitution across Education Groups

With the estimation of wage gaps between different education groups, this study recognizes the possibility of perfect substitution between high school-educated workers and college-educated workers[20]. In this section, a model that assumes perfect substitution across education groups (i.e., assuming imperfect substitution across age groups only) is considered and the wage function estimated. In other words, the evolution of the return to schooling is analyzed under the assumption that different education groups of the same age are perfect substitutes in production. The estimated results are shown in Table 6. The estimated coefficient of the age group-specific relative supply is

[20] This finding is similar to the case of Japan (Ohtake, 2006), but not the other countries (the U.S., U.K.).

Table 6. Models with Perfect Substitution across Education Groups

Dependent Variable: Hourly Wage	(1)	(2)
Age group-specific relative supply	-0.102** (0.047)	-0.163*** (0.029)
Trend	0.039*** (0.000)	0.060*** (0.001)
Trend^2		-0.001*** (0.000)
Number of observations	231	231
F-value	981.57***	2412.90***
Adjusted R^2	0.972	0.990

Notes: Standard errors in parentheses. Significance level: * 10%, * 5%, * 1%.
This model also includes age effects (omitted due to lack of space).

significant and negative, which confirms imperfect substitution across age groups (σ_A), supporting our results up to this point.

6. Conclusion

This paper examines how changes in the age group-specific relative supply of labor, or aggregate relative supply of labor affect the college-high school wage gap for any specific age group. In terms of labor supply, what accounts for observed changes in the college-high school wage gap for any specific age group? According to the model used by Card and Lemieux (2001), assuming imperfect substitutability across age groups, the college-high school wage gap for a given age group depends on the age group-specific relative supply and the aggregate relative supply of the two types of labor: college educated and high school educated. Also, the effects of the age group-specific relative supply and the aggregate relative supply are dependent on the magnitude of the elasticity of substitution across age groups (σ_A) and the elasticity of substitution between different education groups (σ_E), respectively.

The main findings of this study are the following: First, regarding the elasticity of substitution across age groups, the estimated effects of the age group-specific relative supply of labor are significant and negative, suggesting that different age groups are imperfect substitutes. This implies that changes in the age group-specific relative supply affect the college-high school wage gap, which is consistent with the previous literature (Card and Lemieux 2001; Ohtake 2006; Choi 2013). Although the size of the elasticity of substitution between different age groups is in the range of 8-20, larger than in the U.S., the U.K., Canada, and Japan (Card and Lemieux 2001; Ohtake 2006), it is far from infinite, indicating imperfect substitution. Indeed, the findings show that differing trends of the college-high school wage gaps across age groups can be explained by the age group-specific relative supply of college-educated labor due to the imperfect substitutability across age groups. Looking at subgroups, imperfect substitution between age groups occurs for workers with high experience, especially in small firms. This underlines the role of experience in accounting for imperfect substitution across age groups.

However, as for the elasticity of substitution between education groups, the possibility that different education groups are perfectly substitutable in Korea cannot be ruled out based on these results (see final model at the aggregate level: column 5 of Table 1). In Korea, unlike Western countries, changes in the aggregate relative supply of college-educated labor do not affect the change in the college-high school wage gap, as college-educated and high school-educated workers are homogeneous in production. These results are consistent with Japanese findings (Ohtake, 2006), but inconsistent with those for the U.S., U.K., and Canada, which show imperfect substitutability between education groups (Card and Lemieux, 2001). Looking at subgroup results, however, imperfect substitutability between education groups was found in large firms.

The findings of this study suggest that age (seniority) or experience are the main contributing factors in accounting for the change in the college-high school wage premium for specific age groups in relation to labor supply. This is because the results suggest that it is impossible to explain the change in the college-high school wage gap without imperfect substitutability across age groups. Furthermore, the results indicate that workers in different age groups cannot be perfectly substituted. Thus, improvement in productivity may only be possible through the combination of different age groups, including both younger and older workers.[21] Additionally, these findings have crucial implications for the role of labor supply policy and underline the issues of age groups or inter-generational coexistence.

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