What Happens to the Wage Structure When Nearly Everyone Has a College Degree? The Case of South Korea

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Abstract

This study explores the effects of changes in the overall educational attainment of workers on wage and employment structure, exploiting a college education policy that has been implemented in Korea over the past 60 years. The Korean government determines a college enrollment quota for each year, which limits the number of college freshmen. The quota has been binding in all years. This study first estimates the causal effect of the relative supply of college workers to high school workers on the relative wage using the college enrollment quota as an exclusion restriction. It then develops and estimates a dynamic equilibrium model that explains the changes in educational attainment, wages, and employment structure simultaneously. The estimated model is exploited to conduct two counterfactual experiments and the main findings are: (1) when the college enrollment quota is abolished and every college applicant enrolls in college, four-year college enrollment rate increases by 19.1 percentage points on average and this decreases the college wage premium by 40.6 percentage points on average during the sample period. The percentile wage gaps significantly decrease and the proportion of white-collar workers increases by 9.6 percentage points; (2) if there was no technical progress biased to college-educated workers, the college wage premium would be lower by 20.9 percentage points on average and the percentile wage gaps would decrease substantially.

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1 Introduction

There has been a tremendous increase in educational attainment in South Korea in recent decades. According to the 1960 census, 16.0% of people aged 21-30 were illiterate, 75.3% of people in the same age group had an elementary education or lower, 14.9% had a high school education or higher, and 5.0% had ever attended college. Only 1.4% of the same age group had a middle-school education or lower, and 79.5% had attended two-year or four-year college programs in 2010. South Korea's experience is remarkable even among the many countries that have experienced a rapid increase in educational attainment in the 20th century. A natural question that arises from the statistics is why this increase happened. We can also infer that this change in the overall educational level of people may have affected the wage and employment structure in the labor market. This study mainly investigates the reasons for the sharp increase in educational attainment over the past 46 years and its impact on the wage and employment structure over the past 35 years in South Korea.

An interesting fact is that the increase in educational attainment was achieved under an explicit institutional restriction. The growth of educational attainment might have been faster if educational institutions had been free of interference. The Korean government has adopted the College Enrollment Quota Policy, which allows it to determine the maximum number of students each college can select as freshmen for each year. Thus, the college quota policy has effectively determined the number of college-educated people in the country. The number of applicants has always been much greater than the aggregate college quota. For example, in 1970, the four-year college quota was 43,190, while the number of applicants, as measured by the number of students who took the national college entrance exam that year, was 162,836. In 1990, the four-year college quota was 199,770, while the number of applicants was 894,179. The important feature of this study is to distinguish ex-ante college applications and ex-post educational attainment. One of the main objects of this study is to understand the reasons for the rapid increase in the number of college applicants and to figure out the role of the College Enrollment Quota Policy in influencing educational attainment and labor market structure.

The labor market structure in Korea has also changed noticeably over the past 35 years. First, the trend of wage inequality changed significantly, with a turning point occurring in the early 1990s. Wage inequality decreased from 1980 to the early 1990s in most demographics in Korea. The college/high school wage gap, the 90/10 and 90/50 wage gaps, and the wage gap between male and female workers decreased sharply during this period. Conversely, wage inequality rose again in the early 1990s and kept increasing until the present. The college/high school wage gap was stable during this period, even though the relative supply of college workers grew rapidly. The 90/10, 90/50, and 50/10 wage gaps increased sharply during this period. In terms of the employment structure, the proportions of service-sector and white-collar workers have grown fast during the past 30 years. The ratio of service-sector workers to the entire workforce was about 45%

in 1986, and this increased to about 70% in 2012. White-collar workers comprised about 30% of the workforce in 1986 but increased to about 50% in 2013.

This study investigates the rise in educational attainment and the changes in the labor market structure using both regression models and a dynamic equilibrium model. This study exploits a methodology suggested by Katz and Murphy (1992, KM model) to examine the roles of demand and supply factors in shaping the changing patterns of the college wage premium in South Korea. This study also estimates a model by Card and Lemieux (2001, CL model) to explore the differential changes in the college wage premium by demographic subgroup as defined by potential experience and gender in a demand and supply framework. After these estimations, this study builds a dynamic equilibrium model reflecting the key regression results. An equilibrium model is necessary to explain the phenomena simultaneously and synthetically. This study is closely related to previous studies that employ an equilibrium model to explain changes in labor market structure and other economic phenomena (Heckman, Lochner, and Taber, 1998; Lee and Wolpin, 2006, 2010; Johnson and Keane, 2013; Dix-Carneiro, 2014) but the equilibrium model in this study is built to reflect the institutional characteristics of the Korean education system and to be closely connected to the IV estimation results of the KM and CL models. The college enrollment quota plays an important role for identifying key parameters in both the simple estimation models and the equilibrium model, as it predicts the ratio of college workers to high school workers for each school cohort and is considered to be exogenously determined.

More specifically, this study first replicates the KM approach using Korean data to see the overall relationship between the wages of college workers relative to high school workers and their relative supply and to check the trends of the relative demand for college-educated workers. Their study and most subsequent studies, however, do not explicitly reveal how the aggregate supplies of college and high school workers are determined, which leaves the possible endogeneity problem unsolved. If the unobservable demand shocks systematically affect the relative aggregate supply, then OLS estimation of the KM model could be biased. This study constructs the proportion of college workers to high school workers for each year predicted by the college enrollment quota and cohort size. This study then estimates the KM model with the IV estimation using the predicted ratio as an instrument for the actual relative supply, and compares the results with those from the OLS estimation.

The estimation of the CL model is also conducted to understand the differential change in college wage premium by demographic subgroups. Card and Lemieux (2001) provide a model that regards different age groups as imperfect substitutes. This model is useful for explaining the differential changes in the college wage premium by age group in a demand and supply framework. They did not, however, deal with the endogeneity problem in both the aggregate relative supply and the relative supply by age group. In this case, two instruments are needed for the two endogenous variables to consistently estimate parameters for the elasticity of substitution between college and high school workers and that between different age groups. The college enrollment quota is exploited to make the two instruments because it specifies not only the ratio of college-educated workers to high school-educated workers at the aggregate level for each year, but also the ratio for each birth cohort. This study estimates the CL model with the IV method using the predicted ratio of college-educated workers to high school-educated workers for each potential experience group and for all workers as instruments, and compares the results with the OLS estimation results. Secondly, this study applies the CL model to estimate the elasticity of substitution between male and female workers.

The KM and CL models are successful in explaining changes in the college wage premium, both in the aggregate worker group and demographic subgroups in the Korean labor market. The key estimation results of the KM and CL models are: (1) college workers and high school workers are not perfect substitutes and the OLS estimate of the elasticity of substitution between college workers and high school workers is biased upwards; (2) the relative demand has grown in a way that increases the college wage premium, and there might have been a structural break in the growth of the relative demand in the early 1990s that accelerated the increase in the college wage premium; (3) different potential experience groups is not be perfectly substitutable; (4) the relative demand trend for college workers may differ by experience group; (5) the substitutability between male and female workers is estimated differently by model, but male and females workers are estimated to be very highly substitutable in more flexible models; and (6) the relative demand trend for college-educated workers has grown only for male workers.

This study builds a dynamic equilibrium model that explains the changes in educational attainment and labor market structure simultaneously. The model economy consists of the manufacturing and service sectors. In each sector, output is produced by nested CES technology that uses human capital in two occupations and physical capital as inputs. It is assumed human capital in white-collar occupations and physical capital consist of a composite factor, and that each sector utilizes this composite and human capital in blue-collar occupations in the highest order of the nests for production. Human capital in each sector-occupation is a CES composite of human capital by high school-educated and college-educated workers employed in that sector-occupation. Human capital for each sector-occupation-education group is made up of the aggregate labor supplied by younger and older workers in the sector-occupation-education group. Male and female workers are assumed to be perfectly substitutable in the model. The assumptions on perfect or imperfect substitutability between different types of human capital in the production function are based on the IV regression results.

Agents are heterogeneous by their demographics and unobservable shocks in each period. The economy is composed of overlapping generations aged 19-62. Individuals are initially high school or middle school graduates at age 19. High school graduates under age 23 sequentially make decisions. The four-year college application process begins first, and individuals for whom the best path is attending four-year college apply. The number of four-year college enrollees is determined at a level that is lower than or equal to the four-year college quota. After completing the four-year college admission process, the two-year college application process begins. People whose best option among the remaining alternatives is entering two-year college apply. The number of two-year college entrants is also determined within the two-year college quota. Both four- and two-year college quotas work as an institutional restriction that determines the maximum possible number of college enrollees in the model. If people attend four- or two-year college, it is assumed they complete their degree. People who do not attend four- or two-year college choose among the remaining five alternatives: work in one of four sector-occupations or work at home. Middle school graduates and people over 22 who are not enrolled in college are not allowed to apply for college, so they also choose among the five alternatives.

The equilibrium model is estimated by the simulated method of moments. The estimated model fits key moments quite well. The estimated model is used to conduct several counterfactual experiments. First, this study evaluates the effect of the college enrollment quota policy on educational attainment and labor market structure by manipulating its level variously. The results from this counterfactual experiment show that the college quota policy has played a very important role in shaping educational attainment and thereby affecting labor market structure. In the counterfactual that there is no college quota and that all applicants can enter college, the four-year college enrollment rate increases by 19.1 percentage points on average during the sample period, even though the number of four-year college applicants decreases significantly. This reduces the college wage premium. For example, the college wage premium was lower than 16% after 2010 in the experiment while the actual premium is stable at about 57% during the period. Wage inequality measured by the 90-10, 90-50, and 50-10 wage gaps also decreases significantly under the regime without the college enrollment quota.

Secondly, this study assesses the importance of technical progress biased toward college workers for determining the changes in demand for education and wage structure. In the counterfactual that there is no technical progress biased to college workers, fewer people apply for four-year college. The college/high school wage gap is significantly reduced in the counterfactual. For example, the college wage premium became 19% in 2014 in the counterfactual, which is a 38-percentage point decrease compared to the baseline model. Wage inequality measures such as the 90-10, 90-50, and 50-10 wage gaps are much smaller in the counterfactual than the baseline model after the late 1990s. The results show that technical progress biased toward college-educated workers has increased wage inequality since the early 1990s in Korea. It has also offset the effect of increasing supply of college workers on the college wage premium so that the college wage premium has been stable since the early 1990s and the college application and enrollment rates have increased.

This paper unfolds as follows. Section 2 explains stylized facts on the changes in educational attainment and wage structure in Korea. Section 3 explains the Korean college enrollment system and the College Enrollment Quota Policy. Section 4 introduces data used in this study. Section 5 explains and conducts regression analysis. Section 6 builds a dynamic equilibrium model. Section 7 explains an estimation method. Section 8 reports estimation results of the equilibrium model. Section 9 conducts counterfactual experiments. Section 10 concludes.

2 Stylized Facts

2.1 Rise in Educational Attainment and the Number of College Applicants

Figure 1 shows high school, four-year college, and college (both four- and two-year college) enrollment and graduation rates for 1920-1989 birth cohorts.[1] The high school enrollment rate was 6.9% for the 1920 birth cohort and 99.1% for the 1980 birth cohort. The high school enrollment rate is greater than 98% for all school cohorts who were born after 1972. For cohorts born between 1920 and 1980, the high school enrollment rate increased by 1.83 percentage points annually. The high school graduation rate is high in Korea, so the difference between high school enrollment and graduation rates is small. Among people who ever enrolled in high school, the average high school dropout rate is 1.78% among high school enrollees over the sample periods.

Figure 1 also presents a rapid rise in college education in Korea. The four-year college enrollment rate increased gradually from the 1920 cohort to the 1958 cohort and started to increase rapidly after the 1958 birth cohort. The four-year college enrollment rate for the 1920 birth cohort is 2.3%, and 16.5% for the 1958 birth cohort. The rate is 36.8% for the 1970 birth cohort and 58.8% for the 1989 birth cohort. The four-year college enrollment rate increased by 1.36 percentage points annually, on average, between the 1958 and 1989 birth cohorts. The average dropout rate among four-year college enrollees is 6.72%. The two-year college enrollment rate was very low before the 1955 cohort, and started to increase sharply from the 1960 birth cohort, reaching 27.6% for the 1989 birth cohort. The college enrollment rate is 86.4% for the 1989 birth cohort.

Even though the college enrollment rate has increased rapidly in Korea, as shown in Figure 1, the number of people who apply to college has increased more dramatically. Figure 2 shows the four-year college application rate and four-year college enrollment rate measured at age 35 for the 1950-1994 birth cohorts. The red line with circled dots represents the ratio of four-year college applicants at age 19 to cohort size for each birth cohort. The green line with plus dots represents the ratio of four-year college applicants at 20 or older to cohort size for each cohort. In Figure 1, the blue line with rectangles shows the four-year college enrollment rate measured at age 35. This figure shows that the number of high school students who wanted to enter four-year college at age 19 has been significantly greater than the number of actual four-year college enrollees. The discrepancy

[1] Since the EAPS, which is data used to make the figure, started to survey in 1986. Educational attainment for people who were born before 1947 is measured by the 1986 survey. Conversely, educational attainment for people who were born after 1975 is calculated with the 2014 survey.

between the number for four-year college applicants and that of four-year college entrants has entailed many four-year college re-applicants, who are represented by the green line. In Korean college education, it is important to distinguish between ex-ante college applications and ex-post college enrollment. This study will show that the explicit restriction on college education supply through the College Enrollment Quota Policy has generated the discrepancy and has approximately determined ex-post educational attainment.

Figures 1 and 2 show that the numbers of college applicants and college enrollees have increased enormously with the high growth rate in Korea. The first question that arises from the figures is "why has there been a rapid increase in the number of college applicants in South Korea over the past 65 years?" The second question is "how has the increase in educational attainment affected the labor market structure in Korea?" This study attempts to answer these questions quantitatively.

2.2 Changes in Wage Structure

I establish stylized facts for the trends of wage inequality in several dimensions in Korea for the years 1980-2014. Figure 3 describes the log hourly wage gaps between different percentile wages. The 90/10 log wage gap decreased sharply from the early 1980s to the early 1990s. The ratio of the 90th percentile wage to the 10th percentile wage was 5.72 in 1980 and 3.96 in 1992. It began to increase from the mid- 1990s and reached its peak in 2008 when the ratio was 5.39. It went down from 2008 to 2012, and then started to increase again from 2012. The wage difference between the 90th percentile and 50th percentile shows a similar pattern: it declined from 1980 to the early 1990s and consistently increased from the mid-1990s. The wage gap between the 50th percentile and the 10th percentile has been relatively flat during the sample period. The wage gap decreased from 1983 to 1987 and increased from the early 1990s to the late 2000s with a slow growth rate. All the measures commonly show that wage inequality decreased from 1980 to the early 1990s and increased from the early 1990s to the late 2000s in South Korea.

Figure 4 depicts the relative wages and relative labor supply of college workers to high school workers during the years 1980 to 2014. The relative labor supply of college workers has constantly increased during the period but the growth rate accelerated from the late 1980s when males who enrolled in college at the time when the college quota increased significantly, started to enter the labor market. From the late 1980s to the early 1990s, the relative wage decreased rapidly as the relative supply increased sharply.[2] The growth of the relative wage slowed down after the mid-1990s, even though the relative supply kept rising. In a simple demand and supply framework explaining the changes in college wage premium, the supply factors may not solely account for the stable college wage premium after the mid-1990s.

[2]There was a rapid decrease in the relative wage between 1987 and 1988, while the relative supply increased modestly. This may be related to the dramatic increase in labor movements from 1987. This will be explained in Section 5.

3 College Application Process and College Enrollment Quota Policy in South Korea

3.1 College Application and Admission Process in South Korea

Since 1969, the national college entrance exam has been an essential requirement for college application and admission in Korea, especially for four-year colleges. Many parts of the high school curriculum have been set for the national college entrance exam, and the exam date has been set according to the schedule of the college application process. This subsection explains the history of the college application and admission process after Korea's independence in 1945, and focuses on historical changes in the national college entrance exam. As there is a significant difference between four-year college and two-year college in the application and admission process, I explain the difference between them in detail. These institutional content will be reflected in the construction of the structural model. I first introduce the history of the application and admission process for four-year college, and then explain it for two-year college in Korea over the past 70 years.

Before 1969, the most important determinant for four-year college admission was an individual university admission exam ("Bon-Go-Sa") held by the college to which the student had applied. The questions in the individual university admission exam were very difficult, so that the colleges could sort the students efficiently.[3] Before 1969, the national college entrance exam was held only in 1954, 1962, and 1963. After 1968, students could take the national college entrance exam for four-year college admission in most cases.[4] The Korean government adopted the Preliminary College Entrance Examination in 1969[5] and it became the first national college entrance exam to be held consistently in Korea. This was a qualifying examination that gave students who passed it

[3]The high level of difficulty of the exam became an important reason for the abolition of the individual university admission exam in 1982. It was difficult for students to solve the problems only with study in high school, many students relied on private tutoring or private institutions that help students prepare for the exam. The New Military that took the power after the military coup in 1979 announced the abolition of the individual university admission exam and banned private tutoring in "July 30 Education Reform" in 1980.

[4]Colleges firstly adopted Early Admission System in 1997 to sublate the admission system that emphasizes the national exam score too much and to diversify college admission process. This admission process mostly emphasizes grade and other activities that students achieve in high school and interview or test by college in admission decision. The Early Admission System has two types according to its application timing: First Semester Early Admission and Second Semester Early Admission. First Semester Early Admission completes application and admission process in the first semester of 12th grade and students who receive an admission in this process do not need to take the national college entrance exam. The Second Semester Early Admission recruits students in the second semester. Students who receive an admission through this process should take the national college entrance exam and should pass a minimum criteria set by admitted college in most cases. The First Semester Early Admission was an exception that students did not need to take the national college entrance exam for four-year college enrollment until it was abolished in 2010. Its proportion was about 5-10% of the entire four-year college quota so that most students who applied for four-year college took the national college entrance exam even in the period when it existed.

[5]The exam in 1969 was held in December 1968. The year 1969 means the expected college entry year of the examinees. The national college entrance exam has been held in November or December and students has enrolled in March of the next year. Following the convention in Korea, the years in this section are denoted to indicate college entry year not the year that the exam was actually held.

an opportunity to apply to four-year colleges. Students who acquired the qualification could take the individual university admission exams devised by colleges to which they applied. The grade in this individual university admission exam mostly determined four-year college admission among the candidates.

From 1974, the score in the Preliminary College Entrance Examination started to be reflected in the admission decision with the grade in the individual university admission exam. As the individual university admission exam was abolished in 1982, the result in the Preliminary College Entrance Examination and high school grade were reflected in the admission decision. In 1982, the national college entrance exam changed its name to the Achievement Exam for College Admission (the author's translation) and it was held until 1993. The current national college entrance exam, the College Scholastic Ability Test (CSAT) has been held since 1994. Before the early 2000s, the score in the national college entrance exam and the individual university exam before its abolition were deterministic factors that dominated four-year college admission results. Since the early 2000s, the Korean government has tried to reduce the importance of the CSAT in college admission by diversifying the college admission process to foster students with diverse talents and to support the school system.[6] As a result, the four-year college application and admission system has become more complicated recently, but most students who plan to apply for four-year college take the national college entrance exam, which is still considered very important for four-year college admission.

The national college entrance exam has been less important for two-year college admission. Before 1979, the national exam was not essential for two-year college application and was not reflected in the admission decision. The individual college exam was important for two-year college admission during this period. The Preliminary College Entrance Examination score was first required for two-year college application from 1979, and the score from the exam was reflected in the admission decision. A Special Admission Type, however, was adopted in 1989 and does not require the national college entrance exam score for application and admission. This admission type is basically aimed at selecting two-year college enrollees among vocational high school students or workers in industrial sites. The proportion of students admitted to two-year college was more than 30% in the early 1990s, a percentage that doubled to approximately 60% recently. In addition, two-year colleges currently select more than 80% of their students by the Early Admission System, which does not require the national college entrance exam score in most cases.

In summary, the national college entrance exam has been essential and very important for four-year college entrance. On the other hand, it was not essential for many years, and currently the proportion of two-year college admissions that require the national exam score is small. Based on these facts, this study takes the number of people who took the national college entrance exam as

[6] As the national college entrance exam has been a very important for college admission, students has tended to focus less on school classes and to depend on industrialized private teaching institutions for helping students prepare for the national exam. High private education cost and collapse of school system by this college admission system has been pointed out as one of the biggest problem in the Korean education system.

the number of four-year college applicants.

Another important characteristic of the college application process in Korea is that the four-year college application process used to start first and then the two-year college application process proceeded after the four-year college admission process was completed.[7] Students could apply to only a limited number of four-year colleges, while they could apply to many two-year colleges.[8] Because of this application system, a significant number of students who failed to enter four-year college used to apply for two-year colleges after four-year college admission process is finished. It had been criticized that two-year colleges cannot raise skilled workers needed in the industrial sites with this application system. In addition, some two-year colleges could not select students up to their quota in many years as a significant number of admitted students did not finally enroll.[9] Facing these problems, the government diversified the application process by introducing the Special Type Admission and the Early Admission System to select more students well matched to the purpose of two-year college education. This increased the possible number of applications for two-year colleges to help these colleges fill their quotas.

3.2 College Enrollment Quota Policy in Korea[10]

One distinctive institutional characteristic of the Korean college admission system is that the Korean government determines or approves the maximum number of students each college may select as freshmen every year. This is called the College Enrollment Quota Policy and has been enacted for more than 60 years.[11] More specifically, the Ministry of Education specifies the maximum number of freshmen each college may select for each major. Table 1 shows the college enrollment quota for the College of Engineering and the College of Agriculture at Seoul National University in 1958 as an example. This is a translated version of the actual college quota table in 1958 Education Statistics. For example, the quota policy stipulated that the Department of Textile Engineering select 40 freshmen at most in 1958, while the Department of Electronic Engineering could select 50 students at most. If we add all the college major quotas for each year, we can get an aggregate college quota in the entire nation for the year.

Lee (2001) explains that the college enrollment quota is determined the following way. First,

[7] This timeline of the college application process was common until the late 1990s. It started to change vastly after the introduction of the Early Admission Type.

[8] The number of possible applications has been changed for both types of colleges. Currently, the number of four-year colleges for which students can apply is six in the Early Admission System and three in the General Admission System. The number was smaller when the Early Admission System did not exist. There is currently no limitation in the number of two-year colleges for which students can apply.

[9] This might be because many of them decided to prepare for the national college entrance exam again to enter four-year college.

[10] The explanation in this section is based on Kang et al. (1986) and Lee et al. (1999)

[11] The author does not have information on the exact year the College Enrollment Quota Policy was adopted, in spite of many investigations. The information on the oldest quota the author has is the 1956 college quota. As there is literature that reports a reduction in the college quota in 1956 (Kang et al., 1986, p. 56), it is inferred that the adopted year is at least before 1956.

the Ministry of Education sets a guideline for adjusting the college enrollment quota compared to the previous year's level. The Ministry of Education notifies every college of the size of the change in the college quota by broadly defined majors. Each college decides on and reports the size of the increase or reduction by major within the size of the change in the quota determined by the Ministry of Education. The Ministry of Education collects the reports from colleges and checks their ability (in terms of faculty size and facilities) to accommodate the quota amount of college entrants. The Ministry of Education confirms the new college enrollment quota in the cabinet council and reports it to colleges. The quota adjustment is made every year and is announced publicly several months before the national college entrance exam in general.

Modest adjustments of annual college enrollment quotas are made through the above process; however, drastic changes in the college enrollment quota policy have been accompanied by political regime change or change of president. The following classification of historical changes of the college enrollment quota policy is generally accepted by education scholars. The first period was from 1945 to 1960, when the numbers of colleges and college students expanded rapidly. Korea became an independent country in 1945 after the end of WWII and the US Military Government ruled the southern part of Korea from 1945 to 1948. The military government tried to expand higher education and allow colleges to manage their work autonomously. The Republic of Korea Government (South Korea) was established in 1948 and the first president retained the autonomous college policy. Political and social factors such as land reform, competition with North Korea, the Temporary Act on Determent of Enlistment in 1950, and the increase of local colleges during the Korean War also contributed to the increase in college education.[12] Responding to the rapid increase in colleges and college students, there was also a move by the government to regulate the establishment of colleges in order to maintain or improve the quality of colleges. The Ministry of Education enacted the Decree on Standards for the Establishment of Universities and Colleges in 1955, which stipulated that colleges should meet criteria on faculty and facilities. This was followed by a reduction of 6,710 in the college quota in 1956. The criteria, however, were demanding during this period, so the government did not effectively enforce the decree according to these criteria and many colleges did not meet the requirements (Kim et al., 2014). In 1945, there were 19 colleges and 7,819 college students. These numbers increased to 85 and 101,041, respectively, in 1960 representing increases of 4.5 and 12.9 times the original numbers.

The second period was from 1961 to 1980, when the government controlled and suppressed

[12]The Land Reform Act introduced in 1949 forced landlords to sell their land at low prices to the government, which then sold this land to peasants at low prices. As there was an exemption that landlords did not have to sell their land if they used it for educational purpose, some landlords established colleges instead of selling their land at low prices. The Temporary Act on Determent of Enlistment led to an increase in the demand for college education, as young males could delay mandatory military service by enrolling in college. The Korean government continued to provide college education during the Korean War (1950-53) by providing it in local areas temporarily, while college education was provided mostly in Seoul before the war as the Seoul area was damaged severely by the war. This became a momentum for the establishment of national colleges in local areas.

the number of college students. A military coup occurred in 1961 and the new president, who governed Korea from 1961 to 1979, started to control colleges directly instead of allowing colleges to manage their works for themselves. The Military Government enacted the Temporary Exemption Law about Education in 1961, which reduced the number of colleges from 71 to 50. By closing 21 colleges, the government decreased the college enrollment quota from 91,540 to 66,410.[13] As some private colleges selected more students than their assigned college quotas, responding to the decrease in the college quota by the Temporary Exemption Law about Education, the Military Government enacted the 1965 College Student Quota Act, which controlled the college quota more strongly.[14] This act became a frame for the college enrollment quota policy for the next 30 years in Korea.

The third period was from 1981 to 1987, when the Korean government expanded the college quota. Another military coup occurred in 1979 in the interim government established after the assassination of the previous president. The New Military Government announced the Graduation Quota Policy in the July 30 Education Reform of 1980. The main content of the Graduation Quota Policy was that the government determined the graduation quota, which was the number of students who could finally graduate from college for each college entry cohort. The college enrollment quota was set to be greater than the graduation quota. The plan was to drop from colleges excessive students selected above the graduation quota. The policy was first enacted in 1981 and the college enrollment quota increased by 30% for four-year colleges and by 15% for two-year colleges as the graduation quota was set at a level similar to the previous quota. As the government finally did not drop the excessive students, however, the graduation quota policy actually played the role of increasing the number of college students. The increased quota in 1981 remained almost constant until the early 1990s without much change.

The last period is characterized by the liberalization of the college quota that accompanied the increase in the college quota. The first civilian government was launched in 1993, and this government announced the liberalization of the college quota in the May 31 Education Reform in 1995. This policy allows private colleges in a non-capital area to set the college quota for themselves if they meet basic requirements such as faculty size and facilities. The government still determines the enrollment quota for the national colleges, and regulates the quota for private colleges in the capital area based on the Seoul Metropolitan Area Readjustment Planning Act (Chang, 2009).[15] Much of the authority to adjust the college quota that the government had, however, was handed

[13] Here, the college quota is the sum of four- and two-year college quotas. The four-year college quota is calculated by the sum of four-year college quotas for adjacent four-year periods. The two-year college quota is the sum of two-year college quotas for two adjacent years.

[14] This act required colleges to store admission letters and the list of students so that the government could check whether colleges selected students more than the prescribed quotas. In addition, the adjustment of college enrollment quota could be possible only after the agreement in the Cabinet council even for one major in one college after this act while the quota used to be determined by vice-minister of the Ministry of Education arbitrarily before the act (Lee et al. 1999).

[15] The quota for medical schools and teaching colleges is still regulated by the government as well.

over to colleges after the college quota liberalization policy. Civilian governments thereafter have maintained the basis of the liberalization policy of the college enrollment quota.[16]

3.3 College Application and College Enrollment Quota from Data

Although the rise in educational attainment has been rapid in Korea, it has been achieved under institutional restrictions such as the college enrollment quota, and the increase in the college application rate has been faster than the increase in the college enrollment rate. Especially for four-year colleges, the number of four-year college applicants has been much greater than the four-year college quota so that only part of the applicants could enter four-year colleges. In Korea, therefore, distinguishing ex-ante college applications from the actual college enrollment is important to accurately understand the choice of college education by individuals. This subsection checks the changes in college quota, the number of college enrollees, and that of college applicants over the past five decades. This confirms the discrepancy between the ex-ante college application and the actual acquisition of college education from data. The four-year college quota has been binding in all sample periods, while the two-year college quota was not binding for many years. This difference is used to separately identify the numbers of four-year college applicants and two-year college applicants.

Panel (a) of Figure 5 shows the four-year college quota, the number of four-year college enrollees, the number of four-year college applicants among 12th graders, the aggregate number of four-year college applicants (the sum of four-year college applicants among both 12th graders and high school graduates) and cohort size for 1961-2014 college entry cohorts. Firstly, we can find that the four-year college quota increased largely in initiatives such as the introduction of the graduation quota policy in 1981 and the liberalization of college quota in 1995, while it changed slightly in most other periods. Secondly, the number of four-year college admissions is almost the same as the four-year college quota, which means that almost every four-year college had more applicants than their assigned quota. Third, the number of four-year college applicants is much greater than the four-year college quota in all sample years. Fourth, this discrepancy between the number of four-year college applicants and the four-year college quota has entailed many four-year college re-applicants who applied for four-year college after high school graduation. Panel (b) of Figure 5 presents the two-year college quota, two-year college admissions, and cohort size. This figure shows that most two-year colleges also received more applicants than their assigned quotas in the sample periods.

Figure 6 compares the ratio of college quota to cohort size from the administrative data and the

[16] Chang (2009), however, explains that the Korean government strengthened regulation against colleges again from 2005 initiated by 'Plans for College Liberalization and College Restructuring (the author's translation)' in December 2004. The government increased the criteria for college establishment and strongly asked existing colleges to satisfy the requirements while previous civilian governments tended to overlook colleges that did not follow the rule. The government also encouraged colleges to decrease quota by subsidizing colleges that reduce the quota. A recent controversial issue is how the government should adjust college quota facing decreasing cohort size.

actual college enrollment rate from the EAPS data for four-year and two-year colleges, respectively, to check whether they are consistent and to understand the interaction between the college quota policy and behaviors of students. Panel (a) of Figure 6 shows the ratio of four-year college quota to cohort size from the administrative data and four-year college enrollment rate from the EAPS by school entry cohort. The ratio from the administrative data is the predicted four-year college enrollment rate for each cohort in the sense that it should be the same as the actual enrollment rate if the four-year college quota is binding and there is no college re-applicant (all students enter college at age 19, which is the age of students right after high school graduation). This figure shows that the four-year college entry rate is significantly lower than the ratio of the quota to cohort size at age 19 but becomes slightly greater at age 20 than the predicted ratio. The fraction of four-year college enrollees among 12th graders is lower than the predicted ratio because some applicants in earlier birth cohorts enter four-year college at age 20 or older and take up some of their seats. Many people who fail to enter four-year college at age 19 apply for four-year college again a year later, thus four-year college enrollment rate at age 20 becomes slightly greater than the predicted ratio. Panel (b) of Figure 6 shows the ratio of the two-year college quota to cohort size from the administrative data and the two-year college enrollment rate from EAPS. Two-year college enrollment rates at both age 19 and 20 are below the predicted ratio in many years. This means the number of two-year college attendees was less than the two-year college quota for many years.[17][18]

These figures have important implications for the separate identification of four-year college and two-year college applicants, respectively. In this study, the number of four-year college applicants is identified by the number of people who took the national college entrance exam, considering the institutional characteristic that it has been essential for four-year college application but not essential for two-year college application for many years. The number of two-year college applicants is identified by two-year college enrollees in the years when the number of two-year college attendees was less than the two-year college quota.

Finally, I briefly discuss the possibility that the college enrollment quota has been endogenously determined. The exogeneity of college enrollment quota is an important condition needed in the following analyses. It might have been endogenously determined in the sense that the government

[17]This graph seems inconsistent with Panel (b) of Figure 5, which shows that there have been more two-year college applicants than the two-year college quota. As explained in Section 3.1, this difference may exist because of many students who were admitted to two-year college but did not enroll finally.

[18]I also compare the predicted ratio and actual ratio using the Population Census for the years 1960-2010 in Figure A2 in Appendix B. The reason why I present the actual college entry rate from EAPS (1986-) is that it is an annual survey, so I can check the changing college enrollment rate by each age, even though its time span is shorter. The census is quinquennially surveyed so the changing pattern can be checked by broader age windows. The census also shows that the expected four- and two-year college enrollment rates by cohort size and college quota predict the actual four- and two-year college enrollment rates well for the longer periods. The actual four-year college enrollment rate is slightly above the predicted enrollment rate in most years, while there are many years when the actual two-year college enrollment rate is below the predicted two-year college enrollment rate.

has sought to determine college quotas in the way to develop the national economy. It is difficult, however, to expect the future labor market conditions precisely. Adjusting college quota every year elastically according to the expectations is also difficult. I try to discuss it by referring policy reports in the past and checking the facts in data.

If we see four-year college enrollment quota before 1980 in Panel (a) of Figure 5, college enrollment quota increased slowly even though cohort size and the number of four-year college applicants increased very rapidly. This is consistent with the strong control and suppression quota policy in this period. The college quota was not elastically adjusted according to economic conditions or labor demand.[19] This contributed the high college wage premium in the early 1980s (See Figure 4).

The drastic college quota changes in other two periods are similar. There was a rapid increase in college quota in 1981 because of the adoption of the Graduation Quota Policy. Even though the increase was substantial in 1981 but there was rare change in the quota from 1981 to 1992. During the period, the increase in the number of four-year college applicants was about 400,000. There was also a rapid increase in college quota from 1993 to 1998 because of the college quota liberalization policy. The change in college quota, however, was very small after the late 1990s. This evidence also shows that college quota was not elastically adjusted and it may not be responsive to current or expected future economic conditions.[20]

[19]The economic growth rate was very high (9.4% on average per annum) during this period and the demand for college graduates also increased rapidly. The quota did not adequately adjusted according to the economic changes. "The growth rate in the supply of four-year college educated workers was only 6.9% per annum from 1970 to 1980 while it was 12.4% for high school workers because of inelastic adjustment of college quota. The increase in the number of managerial positions, technical professionals and office jobs that college students are mostly employed was 352,000 while the growth of college graduates including graduate students was only about 200,000 from 1970 to 1975. We evaluate that there was a shortage of college graduates in this period. The growth of the number of the jobs was about 555,000 but the increase in the number of college graduates was about 280,000 from 1975 to 1980 so that the shortage of college graduates is being intensified (translated by the author from p70 in Kang, Kim and Min (1986). They cite this from Choi (1986)).

[20]I also test the relationship between log college enrollment quota and log real GDP growth rate in Table A1 in Appendix C to examine whether college quota determination is related to economic conditions. The first row shows the relationship between log college quota and log real GDP growth rate in the year when the college quota was determined. The second row shows the relationship between the quota and log real GDP growth rate 4 years after the quota determination when female four-year college enrollees are expected to graduate. The third row shows the relationship between the quota and log real GDP growth rate 7 years after the quota determination when male four-year college enrollees are expected to graduate after the military service. While the relationship is significantly positive when linear trend is assumed, they do not have any significant relationship in other specifications on time trend. If we see the changing pattern of college quota in Figure 5, it is difficult to think that the trend is linear. Higher order trend is likely to be reasonable so that the regression results show that college quota was not responsive to current and future economics growth rates.

4 Data

4.1 OWS

The Occupational Wage Survey (OWS) annually surveys approximately 500,000 regular workers in about 32,000 establishments and it has been compiled by the Ministry of Employment and Labor in Korea.[21] The OWS micro data is currently available for the years 1980-2014. It surveyed establishments that employ ten or more workers from 1980 to 1995, however it has surveyed establishments that hire five or more employees since 1996. I include workers aged 19-62 who were employed in firms that hire 10 or more workers in the sample for consistency across the surveys in different years. The OWS includes the basic demographic information and the labor market outcomes such as monthly earnings, monthly working hours, industry and occupation of the regular workers in the sample establishments. While the OWS has a sample selection issue that workers in the sample are from the establishments that employ 10 or more workers, it has a large sample size and it is considered to have less measurement error issues. I closely investigate the possibility of the sample selection in figures in Appendix A and it is not likely that the sample selection problem contaminates the measures of wage inequality.

4.2 EAPS

The Economically Active Population Survey (EAPS) is a representative household survey in Korea conducted by Statistics Korea. This survey may be comparable to Current Population Survey in the U.S.. The EAPS started in 1963, and it surveys people every month whose age is greater or equal to 15 in approximately 32,000 households in Korea.[22] Micro data for the EAPS, however, is available from the survey in 1986. The EAPS surveys employment status, job search behaviors and basic demographic information but it does not include earnings information. Several additional surveys that complement the monthly EAPS started early 2000s. In 2001, August Supplement Survey (or Supplement Survey by Work Type) started to be compiled and this supplementary survey has expanded to biannual survey conducted in March and August since 2007. The important feature of March and August Supplement Survey is that these include earnings information. This study uses the micro data of the main EAPS from the year 1986 to 2014 to have employment and education information. The August Supplement will be used to check the possible sample selection problem of the OWS in Appendix A.

[21] The Ministry of Employment and Labor defines a regular worker as a worker whose contract period is (or is expected to be) one or more years and earns regular wages or a salary.

[22] From 1963 to June 1988, the EAPS surveyed 17,500 households. Since then, it has surveyed approximately 32,000 households.

4.3 KLIPS

The Korean Labor and Income Panel Study (KLIPS) is a representative panel survey that mainly investigates labor market outcomes of individuals in Korea, which may be comparable to PSID in the U.S.. The KLIPS started to survey in 1998 and it is continuing. The KLIPS surveys people whose age is greater or equal to 15 in approximately 5,000 households in non-rural areas every year. The KLIPS provides detailed information on educational attainment, labor market outcomes and demographics. I extract job transition information from KLIPS exploiting its panel aspect and educational attainment information by family background.

4.4 Other Data

The four-year and two-year college quota data is from Education Statistics by the Ministry of Education for the years 1964-2014 and from old news papers for the years 1961-1963. The number of people who took the national college entrance exam is from old news papers for the years 1969-1993 (1971-1993 for the number of retakers) and KICE (Korea Institute for Curriculum and Evaluation) for the years 1994-2014. The physical capital stock data is from the Bank of Korea for the years 1970-2013 and Pyo (2003) for the years 1961-1969. Initial demographic conditions for individuals are taken from 1% Micro Census for the years 1960-2010. Population size for each birth cohort by year is from the Census in Korean Statistical Information Service (KOSIS).[23]

5 Preliminary Data Analysis

5.1 College/High school Relative Wage and Relative Supply

Assume that the aggregate output of the economy is determined by the following CES production function.

$$Y_t = A_t(\alpha_t S_{ct}^{\frac{\sigma-1}{\sigma}} + (1-\alpha_t) S_{ht}^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where Y_t is an aggregate output, A_t is total factor productivity, S_{ct} is aggregate labor supply by college equivalent workers and S_{ht} is aggregate labor supply by high school equivalent workers.[24] α_t is a time-varying relative factor intensity parameter of college workers and σ is a parameter that governs the elasticity of substitution between the two inputs.

With some algebra under the assumption that wages are set in the competitive market, we can derive equation (2). The (log) time-varying ratio of the factor intensity parameters, $\log(\frac{\alpha_t}{1-\alpha_t})$, can be thought of as the relative demand trend for college workers to high school workers. Equation

[23] Census is conducted quinquennially in Korea.

[24] The aggregate supplies are measured in efficiency units to adjust gender-experience composition changes in the labor market. I follow the calculation method provided in Autor, Katz and Kearney (2008).

(2) shows that the relative wage of college workers to high school workers is determined by relative demand and supply.

$$log\left(\frac{w_{ct}}{w_{ht}}\right) = log\left(\frac{\alpha_t}{1-\alpha_t}\right) - \frac{1}{\sigma}log\left(\frac{S_{ct}}{S_{ht}}\right) \quad (2)$$

$$= \beta_0 + \beta_1 log(\frac{S_{ct}}{S_{ht}}) + X_t\beta_3 + \epsilon_t \quad (3)$$

I approximate the demand factor by observable factors X_t and an unobservable factor ϵ_t, and derive the regression equation (3). I assume that the changing pattern of relative demand has a specific functional form and I estimate the model with various functional forms to test whether the estimation results are sensitive to the functional form assumptions. The parameter β_1 presents the (negative) inverse of the elasticity of substitution between inputs. The parameter β_3 represents the shape of the relative demand change.

Figure 7 presents the relative wage and relative labor supply of college workers to high school workers deviated from a linear trend. The figure clearly shows the negative relationship between the relative supply and relative wage. Table 2 presents the OLS estimation results for the regression model (3). The results in different columns are from different specifications on the demand trend X_t in equation (3). Column (1) reports the estimation result for the model without any demand trend. The estimate for β_1 is -0.140. The model explains the variations in the relative wage quite well, even without any demand trend (R^2=0.817). The second column shows a result from the model with a linear demand trend. The estimate of β_1 is -0.299, which means a 1% increase in the relative supply leads to a 0.299% reduction in college premium. It also implies the estimate of the elasticity of substitution between college and high school workers is 3.34. The estimate for the relative demand growth is 0.14, which implies that the demand trend increases the relative wage of college workers by 1.4% annually. Considering the fact that the figures illustrate the trend of the wage gap between various groups was reversed in the early (or mid) 1990s, I report the estimation result for the model assuming that the demand trend was changed structurally in 1991 in column (3). The estimation result from the model shows there is no significant demand trend that favors college workers before 1992, and the relative demand trend started to increase the college wage premium after 1991. The estimated elasticity of substitution is 4.48. The model that includes a structural demand change in 1991 explains the variations of the relative wage (R^2=0.925) better than the model without the structural change (R^2=0.851). The result from the model allowing for a quadratic demand trend is presented in column (4) and shows that the relative demand growth accelerated after the early 1990s. This model also explains the variations of the relative wage well (R^2=0.892). The results in column (5)-(8) are for the models that include the unionization rate or minimum wage to the models in columns (2) and (3). As Figure A3 in Appendix D provide suggestive evidence that these labor institutions may have affected the relative wage significantly in the late 1980s, I test the model with these variables. The results present that the higher unionization rate and minimum wage reduce the college wage premium as predicted, and the time trends are comparably estimated. The elasticity of substitution is estimated to be slightly smaller when these labor market institution variables are added to the previous models. The models with the labor market institutions explain the variations in the relative wage better, as shown in the higher R^2.

Even though the graphical analyses and estimation results show that the demand and supply framework by Katz and Murphy (1992) accounts for the changes in the relative wage of college workers to high school workers well in the Korean labor market, there is a concern related to the relationship between the relative labor supply and the error term ϵ_t in the regression model. The OLS estimation for the model (3) implicitly assumes that the variation in the relative labor supply is exogenous, but there is no sufficient explanation for why and how it varies. In terms of model (3), the error term ϵ_t can be interpreted as demand shocks deviated from the assumed trend of relative demand. One problem is that college workers (or high school workers) can change their labor supply by either intensive or extensive margins when they face demand shocks.

More specifically, the relative supply of college workers to high school workers is determined by the ratio of college-educated people to high school-educated people, their relative average employment rate, and their relative average working hours.

$$\frac{S_{ct}}{S_{ht}} = \frac{h_{ct}p_{ct}L_{ct}}{h_{ht}p_{ht}L_{ht}} = h_t p_t L_t \tag{4}$$

where h_{jt} is average working hours, p_{jt} is average employment rate and L_{jt} is population size for j educated people (j=c,h). h_t, p_t, and L_t are the relative average working hours, employment rate, and population size of college-educated people to high school-educated people, respectively.[25]

As individual workers can change their working hours (intensive margin) or their employment status can also be changed (extensive margin) in response to demand shocks, it is not certain that the demand shock ϵ_t is not correlated with the relative supply. The proportion of college-educated people to high school-educated people may be more determined with greater complexity by people's education choice long before year t. If people make an education choice based on their future expectation on the returns to education and their expectations are systematically different from the specified trend, the error term ϵ_t can be related to the proportion of college-educated people in the economy. All the components of the aggregate relative labor supply h_t, p_t and L_t, therefore, can potentially be correlated with the error term in model (3). Considering these possibilities, it is not certain that the OLS estimation can provide consistent estimates for the parameters in model (3).

To cope with this problem, I exploit exogenous variation in the ratio of college-educated people

[25]The actual aggregate supply of each group in this study is measured in efficiency units to adjust compositional changes in the labor market. The equation (4) is a simplified calculation for illustrative purpose.

to high school-educated people determined by the college enrollment quota and cohort size as a partial source of variations in the relative aggregate labor supply. I construct the expected relative supply of college workers to high school workers using the College Enrollment Quota Policy in South Korea. This policy specifies the number of college students for each school cohort (and thereby automatically the number of non-college students) so that we can predict the ratio of college-educated people to high school-educated people in any year. I estimate the model (3) using the instrumental variable approach with this constructed variable. More specifically, I calculate the predicted numbers of college and high school workers in the following way:

- The predicted number of four-year college workers in year t (Q_{1t}): the sum of four-year college quotas for cohorts aged between 25(24) and 63 for the years before 1994 (after 1993).
- The predicted number of two-year college workers (Q_{2t}): the sum of two-year college quotas for cohorts aged between 24(23) and 63 for the years before 1994 (after 1993).
- The predicted number of high school or lower workers in year t (Q_{3t}): the difference between "the entire population of people whose age was 22(21) and 63" and "the sum of the predicted four-year and two-year college workers" for the years before 1994 (after 1993).[26][27]

The predicted ratio of college equivalent workers is calculated as the ratio of the sum of the predicted four-year college workers and half of the predicted two-year college workers to the sum of predicted high school workers and half of predicted two-year college workers ($\frac{Q_{1t}+\frac{1}{2}Q_{2t}}{Q_{3t}+\frac{1}{2}Q_{2t}}$) following the treatment of a unit of two-year college workers as one half college and one half high school worker in Autor, Katz and Krueger (1998), Card and Lemeiux (2001) and Autor, Katz and Kearney (2008).

Using the above predicted college and high school workers, I estimate model (3) by the two-stage least squares (2SLS). The following equation is the first-stage regression equation:

$$log\left(\frac{S_{ct}}{S_{ht}}\right) = \pi_0 + \pi_1 log\left(\frac{Q_{1t}+\frac{1}{2}Q_{2t}}{Q_{3t}+\frac{1}{2}Q_{2t}}\right) + X_t\Pi_3 + \zeta_t \tag{5}$$

Figure 8 depicts the relationship between the actual and predicted relative supply deviated from a linear trend. The deviated expected relative supply generally predicts movements of the deviated actual relative supply well. The actual relative supply is more volatile than the predicted relative supply, as the actual relative supply additionally includes variations by changes in the

[26] The time division is to reflect the change in the term of mandatory military service for males. Roughly speaking, the term of military service was about three years before 1994, and has been about two years since 1994. See more specific information on the terms of military service in appendix F.

[27] Males who attended four-year college at 19 before 1994 were supposed to enter the labor market at 26 because they were expected to spend four years in college and three years in the military. The aggregation of the four-year college quota, therefore, is made for people aged 26-62. High school-educated males are expected to enter the labor market at 22 if there is not any delay. The proportion of males in the labor market is substantially greater than that of females; the criteria for the entry age is based on the timing of males' expected labor market entry.

relative working hours and employment rate. The detrended expected relative supply started to increase from 1986 when males who entered college in 1979, the year when there was a noticeable increase in the college quota, were expected to begin to enter the labor market. The growth was accelerated in 1988 when males who attended college in 1981, the year when the Graduation Quota Policy was enacted, were supposed to start to enter the labor market. The growth of the actual relative supply started to increase very rapidly from 1990. A possible explanation for the time gap is that a significant portion of male workers might enter the labor market later than they were supposed to enter without any delay. Additional stay in college because of the discrepancy between the schedule of mandatory military service and the college schedule could also cause later entry into the labor market. For example, if students start military service in April or May, they should stay in college about six months more because colleges in Korea begin their semesters in March and September. Supplemental job search can be another factor. In addition, the relative supply may depend on economic conditions. For instance, many new labor unions were organized during the years 1987-1989 and the minimum wage was first introduced in 1988.[28] These social movements were accompanied by political convulsions, including a pro-democracy movement and constitutional amendment in 1987. These movements might have favored lower wage workers and might have induced those workers to provide more labor supply. This could have offset the increase in aggregate college labor by the influx of new college workers. As another example, significant changes in the relative supply are also observed around periods of sudden economic changes, including the East Asian economic crisis during the years 1997-98 and the global financial crisis in 2008. These possibilities remind us of the necessity to use instrument in the estimation of model (3).

Table 3 shows the first-stage regression results. The expected relative labor supply is strongly related to the actual relative labor supply, regardless of specification on the demand trend. The relationship between the two variables without any other independent variable is reported in column (1), and the estimated coefficient is 0.936. It is 1.577 when a linear trend is added. As seen in Figure 8, that the actual relative supply is more volatile than the predicted relative supply when a linear trend is assumed, the estimated coefficient for the effect of the predicted relative labor supply on the actual relative supply is greater than one and is statistically significant at the 1% level in all specifications that include the relative demand trend. The model explains the variations of the actual relative labor supply very well: R^2 is greater than 0.980 in all specifications that control a time trend. The effects of the unionization rate and minimum wage on the actual relative supply are negative and statistically significant at the 1% level. This raises the possibility that high school equivalent workers supply more labor when market conditions are more favorable to them. Including these variables also makes the model explain the variations in the actual relative labor supply better: R^2 increases.

[28]See Figure A3 in Appendix D.

Table 4 presents the second stage estimation results. Column (1) reports the estimation result for the model without any independent variable other than the relative supply. The estimate is -0.139 and is very similar to the OLS estimate. The result for the model with a linear time trend is presented in column (2). The estimated elasticity of substitution is 1.72, which is about half of the OLS estimate. The estimate for the linear relative demand trend shows that the relative demand increases the college wage premium by 2.8% annually. Column (3) reports estimates for the model with the structural break of relative demand in 1991. The elasticity of substitution is estimated to be 2.78. The IV estimation reports that there was no relative demand trend that favored college workers before 1992. Th relative demand has grown since the early 1990s, and the estimate shows that it increased the relative wage of college workers by 1.1% annually. The model with the structural break fits the variations in the relative wage better than the model without it. Column (5)-(8) presents the results for the models that further include the unionization rate and minimum wage as regressors to the models in columns (2) and (3). Including these variables, especially the unionization rate, significantly improves model fits. For these models, the estimates of the elasticity of substitution range from 2.07 to 3.76. The estimated relative demand trend also implies an acceleration of the relative demand growth in the early 1990s. The estimation results also show that increases in the unionization rate and minimum wage decrease the relative wage of college workers.

The estimate of the elasticity of substitution between college and high school workers is smaller in the IV estimations than in the OLS estimations regardless of specification on the demand trend. This is consistent with the expectation that the relative supply can be positively correlated with demand shocks. I visualize the relationship using the estimate for the demand shocks. If the instrument made by college quota and cohort size is valid, we can consider the residuals from the second stage estimation are estimates for the demand shocks. I show the relationship between the residuals from the second stage regression and the relative labor supply deviated from linear trend in Figure 10. This figure shows that the estimate for the demand shocks, the residuals, are strongly correlated with the detrended relative supply. This raises the possibility of simultaneity bias in the OLS estimation again.

5.2 College/High school Relative Wage and Relative Supply in More Specified Groups

This section investigates the changes in college/high school wage gap by demographic subgroup. Card and Dinardo (2002) point out that skill-biased technological change alone can not successfully explain the changing patterns of college wage premium within some demographic subgroups. I investigate the changes in college premium by experience and gender, respectively, and check whether the SBTC story can explain the changes in wage structure in the subgroups in the Korean labor market. The findings in this section will be also reflected in the construction of a dynamic equilibrium model.

5.2.1 College/High school Relative Wage and Relative Supply by Experience Group

Panel (a) of Figure 11 depicts the changes in log wage difference between college and high school equivalent workers by four potential experience groups (0-8, 9-17, 18-26, 27-35 years of potential experience). From 1980 to 1985, the college wage premium for each experience group was stable. The college wage premium started to decrease first for the least experienced group from 1986 and it decreased from 1988 for other groups. The premium decreased until 1994 for all the groups but the magnitude of decrease was the greatest for the youngest group for the years 1980-1994. The college wage premium increased for the 9-17 years experience group from the late 1990s to late 2000s. The premium was relatively stable for 18-26 years of experience group after the mid 1990s. The college wage premium was stable from the mid 1990s to the late 2000s and it decreased after late 2000 for the 0-8 and 27-35 potential experience groups.

Panel (b) of Figure 11 shows log difference in aggregate labor supply between college and high school workers by the four experience groups. The relative supply of college workers to high school workers has rapidly increased for 0-8 years of experience group since the year 1980. The amount of the increase is dramatic, the aggregate labor supply of college workers was 16.4% of high school workers' labor supply in 1980 and it became 327% in 2014 for 0-8 experience group. The relative supply was stable from 1980 to 1988 for other experience groups and it has risen since the late 1980s. The magnitude of increase in the relative supply is grater for relatively younger groups.

The differential changes in college premium across different experience groups imply that these experience groups are imperfectly substitutable. Another noticeable fact is differential change in college premium across the groups after the mid 1990s. For 0-8 and 9-17 experience groups, the difference in college premium widened even though the growth of the relative supply was almost the same. For another example, the gap in college premium was narrowed between 18-26 and 27-35 experience groups while the increase in the relative supply was greater for 18-26 experience group for the years 1994-2014. This implies that there might be the differential relative demand trends across different experience groups at least after the mid 1990s. Based on these motivational facts, I analyze the differential changes in college premium across different age groups in a demand and supply framework.

To analyze the differential changes in college wage premium by potential experience group, I estimate a model by Card and Lemieux (2001) that is described in equation (6). Their model is an extended version of KM model that assumes different age groups are imperfectly substitutable. In the model, the aggregate labor supply for each education group is a CES composite of different experience groups in the education group.

$$
\begin{aligned}
Y_t &= A_t(\alpha_t S_{ct}^{\frac{\sigma-1}{\sigma}} + (1-\alpha_t) S_{ht}^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} \\
S_{et} &= \sum_j (\gamma_{ejt} S_{ejt}^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}}, \ e = c, h.
\end{aligned}
\tag{6}
$$

where S_{ejt} is the aggregate labor supply by age group j in education group e, γ_{ejt} is a factor intensity parameter for each group and η is a parameter for the elasticity of substitution between different age groups. It is assumed that the elasticity of substitution between different experience groups is the same across high school and college educated workers.

Under the assumption that skill prices are determined in the competitive market, we can derive the following regression model from the equation (6).

$$
log\left(\frac{w_{cjt}}{w_{hjt}}\right) = \gamma_0 - \frac{1}{\eta}[log\left(\frac{S_{cjt}}{S_{hjt}}\right) - log\left(\frac{S_{ct}}{S_{ht}}\right)] + \frac{1}{\sigma} log\left(\frac{S_{ct}}{S_{ht}}\right) + X_{jt}\Gamma_1 + \delta_j + \epsilon_{jt} \tag{7}
$$

where w_{ejt} is a weighted average wage and S_{ejt} is a weighted aggregate labor supply for workers with education e (e=c or h) in age group j. X_{jt} is a vector of the relative demand trend for college workers to high school workers that can differ by subgroup j. δ_j is a vector of age group fixed effects. η represents the elasticity of substitution between different experience groups with the same education. σ presents the elasticity of substitution between college and high school workers.

Column (1)-(3) in Table 5 report the OLS estimation results. The different columns report the results for the models with different specification on the demand trend. The unionization rate is commonly included in the model as a regressor. The first column shows the result with a linear time trend and a structural break in the time trend in 1991. The estimated elasticity of substitution between different experience groups is 11.11 and that between college and high school workers is 3.07. The result also reports that the relative demand that is favorable to college workers started to grow in 1991 while there was not a significant growth in the relative demand before the year. The second column reports the result that allows a quadratic time trend and the estimates for the elasticity of substitution parameters are very similar to that in column (1). Column (3) reports the result that allows more flexible functional form for the relative demand trend. It is assumed that there was a structural break in the demand trend in 1991 and all the time trends can differ by the experience group. The estimated elasticity of substitution between education groups is 3.04 and the elasticity of substitution between experience groups is estimated to 9.17. The estimation with age-group specific relative demand trend explains the variations in college premium better. All the results show imperfect substitutability between different experience groups but they are highly substitutable.

As explained in the previous subsection, the aggregate labor supply for each education group may not be exogenously determined. In model (7), the aggregate supply for each education and experience subgroup is another endogenous variable. To handle the endogeneity problem, I estimate the model (7) using the instrumental variable estimation. The two actual relative labor supply variables are instrumented by the predicted relative labor supply variables which are determined by college enrollment quota and cohort size.[29] The following two equations are the first stage regression equations:

$$log\left(\frac{S_{cjt}}{S_{hjt}}\right) - log\left(\frac{S_{ct}}{S_{ht}}\right) = \kappa_0 + \kappa_1(log\left(\frac{Z_{cjt}}{Z_{hjt}}\right) - log\left(\frac{Z_{ct}}{Z_{ht}}\right)) + \kappa_1 log\left(\frac{Z_{ct}}{Z_{ht}}\right) + X_{jt}\kappa_3 + \upsilon_t \quad (8)$$

$$log\left(\frac{S_{ct}}{S_{ht}}\right) = \tau_0 + \tau_1(log\left(\frac{Z_{cjt}}{Z_{hjt}}\right) - log\left(\frac{Z_{ct}}{Z_{ht}}\right)) + \tau_1 log\left(\frac{Z_{ct}}{Z_{ht}}\right) + X_{jt}\tau_3 + \nu_t \quad (9)$$

where Z_{ejt} is the predicted aggregate supply by workers with education who are in experience group j. Z_{et} is constructed with the same way in Section 5.1. Z_{ejt} is made by calculating the expected number of people with education e and potential experience j determined by college enrollment quota and age given the education level.

Table 6 presents the first stage estimation results. Panel (a) of Table 6 shows the estimation results for the effects of the expected entire relative supply and age-group specific relative supply on the actual age-group specific relative supply. The predicted age-specific relative supply is strongly related to the actual age-specific relative supply regardless of specification on the demand trend. The predicted relative supply for the entire group is not related to the actual age-group specific relative supply. Panel (b) of Table 6 presents the estimation results for the effects of the predicted relative labor supply variables on the actual relative supply for the entire group. The predicted aggregate relative supply is strongly correlated with the actual aggregate relative supply. On the other hand, the predicted age-group specific relative supply does not affect the aggregate relative supply. The first stage regression results in Table 6 shows that both the two instruments satisfy the instrument relevance condition.

Column (1)-(3) of Table 7 report the second stage regression results for the IV estimation. Firstly, the IV estimates of the elasticity of substitution between education groups are comparable across different specifications for the demand trend. It ranges from 2.58 to 2.87 by specification and it is also comparable to the OLS estimate. The estimate for the elasticity of substitution between different experience groups is 15.63 in column (1) and (2) where the demand trend is assumed to be linear with a structural break and quadratic, respectively. When the relative demand trend can differ by experience group, the elasticity of substitution between age groups is estimated to be 4.85. In this specification, the relative demand trend that increases college premium is only observed after 1991 and the growth rate differs by experience group. For example, the relative demand trend

[29]The detailed explanation for the construction of the predicted relative supply by experience group is given in Appendix F.

increased college premium 2.2% per annum for 9-17 experience group after 1991 while there is no significant trend for 27-35 experience group.

5.2.2 College/High school Relative Wage and Relative Supply by Gender

The change in the relative wage of college workers to high school workers differs by gender in terms of the magnitude of the change and the patterns for the years 1980-2014. Panel (a) of Figure 12 presents the changes in the relative wage by gender and it shows a remarkably different trend of the relative wage by gender. For both male and female workers, the relative wage of college workers was barely changed during the years 1980-1987. The college workers had about 3.0 times higher hourly wage than high school workers for females during the period while college workers had about 2.1 times higher wage than high school workers for males. The college wage premium dropped rapidly from the year 1987 to the early 1990s, especially for female workers. The relative wage of college workers to high school workers for females became 2.1 in 1992. The college wage premium became similar between male and female workers in the mid 2000s and it became lower for female workers after the mid 2000s. The college wage premium became approximately 50% for female workers while it was about 83% for male workers in 2014. The relative wage of female college workers has consistently dropped since 1987. The graph also shows a tendency that the college wage premium for male workers has risen since 1994.

The remarkable drop in the relative wage of college workers especially for female workers may be related to more dramatic increase in college enrollment rate for females. The relative supply of college workers to high school workers has consistently increased during the sample period for both males and females but the magnitude is much greater for females (Panel (b) of Figure 12). The aggregate labor supply of female college workers was about 3.6% of the aggregate labor supply of female high school workers and it was 26.4% for male workers in 1980. The ratio became 116% for males and 112% for females in 2014. Another noticeable fact is that the college wage premium for males has increased since the early 1990s even though there have been steady increases in both the relative supply of college workers for the entire workers and that for males. For this rise to happen, there should be a demand trend that increases college premium for male workers or all workers at least after the early 1990s.

For more formal analysis, I estimate the equation (7) where subgroup j indicates a gender group. It is implicitly assumed that all other demographic subgroups are perfectly substitutable and the elasticity of substitution between males and females is the same across high school and college workers. η represents the elasticity of substitution between male and female workers and σ is that between college and high school workers in this application. Table 8 shows the estimation results. The estimate of the elasticity of substitution between male and female workers is sensitive to specification on the demand trends while that between college and high school workers is robust to the specification. Column (1) of Table 8 reports the result when a linear demand trend with a structural break in 1991 is assumed. Column (2) reports the estimation result for the model that assumes a quadratic demand trend. The elasticity of substitution between male and female workers is estimated to be 5.43 in both models. The estimated elasticity of substitution between college and high school workers is 2.60 and 2.43 in column (1) and (2), respectively.

The column (3) and (4) of Table 8 report the results for the models that the differential relative demand trend by gender is added to the models in column (1) and (2), respectively. In these models with more flexible demand trend, the estimated elasticity of substitution between male and female workers become very small and statistically insignificant. The demand trend that increases college premium is only found for males. The column (5)-(8) report the estimation results when the model (7) is separately estimated. The column (5) and (6) report the regression results for males that allow a linear time trend with a structural break in 1991 and assume a quadratic time trend, respectively. The estimate for the elasticity of substitution between male and female workers are statistically insignificant in both models. Column (5) also shows the acceleration in the relative demand growth in 1991. The relative demand has increased since the year 1992 and it has raised college wage premium annually by 1.3% . Column (7) and (8) show the results for females. The estimate for the elasticity of substitution between male and female workers is negligible and statistically insignificant. Any relative demand trend that is favorable to female college workers is not observed. The elasticity of substitution between college and high school workers is greatly estimated for male workers.

5.3 Summary of the Regression Results

The regression results consistently show that college and high school workers are not perfect substitutes. The elasticity of substitution between college and high school workers is estimated to be lower in the IV estimation than in the OLS estimation which is consistent with the concern that the relative supply responds to demand shocks. These results are robust to different specifications on the relative demand trend. The model with a structural break in the relative demand in 1991 explains the variation in college wage premium better and the relative demand growth for college workers is accelerated after the early 1990s in this model. As the use of information technology including computer in the workplace started to rise rapidly from the early 1990s (or the late 1980s) in Korea, it seems like the results are consistent with the story of skill biased technical change at first glance. Adding institutional factors such as unionization rate and minimum wage also improves the explanatory power of the model.

IV estimations for the model with imperfect substitutability between different potential experience groups consistently show that they are highly substitutable but are not perfectly substitutable. The substitutability between male and female workers are not robust to different specifications on the demand trend but they are estimated to be very highly substitutable in more flexible models.[30]

[30] Card and Dinardo (2002) evaluate whether the SBTC story is consistent with the changes in wage structure

6 Model

6.1 Technology

The economy consists of two sectors, manufacturing (M) and service (R). The following nested CES function describes the production technology in each sector.

$$Y_t^s = z_t^s\{\alpha_{1t}^s(S_t^{B,s})^\sigma + (1-\alpha_{1t}^s)[\alpha_{2t}^s(S_t^{W,s})^\nu + (1-\alpha_{2t}^s)(K_t^s)^\nu]^{\sigma/\nu}\}^{1/\sigma},\ s = M, R$$

where z_t^s is a price adjusted total factor productivity, $S_t^{B,s}$ is an aggregate labor supply by blue collar workers, $S_t^{W,s}$ is an aggregate labor supply by white collar workers, K_t^s is physical capital employed in sector s. α_{1t}^s and α_{2t}^s are factor intensity parameters in sector s. ν is a parameter that governs the elasticity of substitution between white collar labor and physical capital. σ is a parameter that governs the elasticity of substitution between blue collar labor and the composite of white collar and physical capital. These parameters that govern the elasticity of substitution are assumed to be the same across the sectors.

An aggregate labor input $S_t^{j,s}$ in sector s and occupation j is composed of college and high school labor inputs employed in sector s and occupation j:

$$\begin{aligned} S_t^{W,s} &= [\alpha_{3t}(S_{ht}^{W,s})^{\rho^e} + (1-\alpha_{3t})(S_{ct}^{W,s})^{\rho^e}]^{1/\rho^e} \\ S_t^{B,s} &= [\alpha_{3t}(S_{ht}^{B,s})^{\rho^e} + (1-\alpha_{3t})(S_{ct}^{B,s})^{\rho^e}]^{1/\rho^e},\ s = M, R. \end{aligned} \tag{10}$$

where $S_{ct}^{j,s}$ is an aggregate supply of college equivalent workers, $S_{ht}^{j,s}$ is an aggregate supply of high school equivalent workers employed in sector s and occupation j and ρ^e is a parameter that determines the elasticity of substitution between college and high school labor inputs and they are assumed to be the same across sectors and occupations.

Finally, it is assumed that the aggregate labor in each sector-occupation-education group consists of labor inputs of two age groups in the category:

$$\begin{aligned} S_{ht}^{j,s} &= [\alpha_{4t}(S_{yht}^{j,s})^{\rho^a} + (1-\alpha_{4t})(S_{oht}^{j,s})^{\rho^a}]^{1/\rho^a} \\ S_{ct}^{j,s} &= [\alpha_{4t}(S_{yct}^{j,s})^{\rho^a} + (1-\alpha_{4t})(S_{oct}^{j,s})^{\rho^a}]^{1/\rho^a},\ s = M, R,\ j = W, B. \end{aligned} \tag{11}$$

where $S_{yet}^{j,s}$ is an aggregate labor supply of workers who is younger or equal to 45 and $S_{oet}^{j,s}$ is an aggregate labor supply of workers who is older than 45 and are employed in sector s and occupation j with education level e. I assume that the elasticity of substitution between young and older workers

partly checking the proportion of computer use by demographic group. The evaluation whether the SBTC story is consistent with the changes in wage structure within demographic subgroups in Korea is deferred in this study because data on difference information technology use by demographic group or other useful data is not found.

(ρ^a) is the same across different sector, occupation and education groups.

It is assumed that the total factor productivity in each sector develops by the following way (Lee and Wolpin, 2006).

$$lnz_{t+1}^s - lnz_t^s = \psi_0^s + \sum_{j=M,R} \psi_j^s(lnz_t^s - lnz_{t-1}^s) + \eta_{t+1}^s, \; s = M, R \tag{12}$$

where η_{t+1}^M and η_{t+1}^R are unobservable shocks drawn from joint normal distribution.

The time dependent factor intensity parameters present factor-biased technical changes and I assume that they evolve linearly and there was a structural break in the evolution in 1991. This reflects the rapid development in information and communication technology and its adoption in the workplace since the early 1990s. As shown in the previous section, there is evidence that the growth of the relative demand systematically changed in the early 1990s and the below parameterization reflects the facts.

$$\alpha_{kt}^s = \alpha_{k0}^s + \alpha_{k1}^s(t - 1961) \;\; if \; 1961 \leq t \leq 1991 \tag{13}$$

$$\alpha_{kt}^s = \alpha_{k0}^s + 30\alpha_{k1}^s + \alpha_{k2}^s(t - 1991) \;\; if \; 1992 \leq t \leq 2014 \tag{14}$$

for k=1, 2 and s=M, R.

$$\alpha_{kt} = \alpha_{k0} + \alpha_{k1}(t - 1961) \;\; if \; 1961 \leq t \leq 1991 \tag{15}$$

$$\alpha_{kt} = \alpha_{k0} + 30\alpha_{k1} + \alpha_{k2}(t - 1991) \;\; if \; 1992 \leq t \leq 2014 \tag{16}$$

for k=3 and 4.

6.2 Individuals

An individual chooses an option that gives the maximum expected present utility among seven alternatives (m=1,...,7) at each period from age 19 to age 22. These seven alternatives are (1) work in manufacturing sector-white collar occupation (m=1); (2) work in manufacturing sector-blue collar occupation (m=2); (3) work in service sector-white collar occupation (m=3); (4) work in service sector-blue collar occupation (m=4); (5) home production (m=5); (6) two-year college education (m=6); (7) four-year college education (m=7). For simplicity, I assume that people are allowed to apply for four-year or two-year college before age 23 and make them complete the degree if they once enroll either of the institutions. Above age 22, people make a choice among the five alternatives (1)-(5) except the people who are already enrolled in college and do not graduate yet.

Before age 23, people first choose whether to apply for four-year college. People whose the best option is entering four-year college apply. If the aggregate number of four-year college applicants is greater than four-year college quota, only the quota number of applicants is selected to enter four-year college actually according to their score. After four-year college admission processes is finished, people decide whether to apply for two-year college. People whose the best option is entering two-year college and those who fail to enter four-year college and has two-year college entrance as the second best alternative apply for two-year college. Likewise the four-year college admission process, only the two-year college quota amount of applicants can actually enter two-year college according to their score if the number of two-year college applicants is greater than two-year college quota in the application year. The remaining people who do not enter four-year or two-year college choose an alternative among the remaining five options.

6.2.1 Value Function

Individual's current value of expected lifetime utility is summarized by the following value functions. As explained, individuals make a choice among seven alternatives before age 23 and they choose among five alternatives after age 22.

$$\begin{aligned} V_a(\Omega_{iat}) &= Max_m \ V_a^m(\Omega_{iat}), \ m = 1, \ldots, 5 \ if \ age > 22 \\ V_a(\Omega_{iat}) &= Max_m \ V_a^m(\Omega_{iat}), \ m = 1, \ldots, 7 \ if \ age \leq 22 \end{aligned} \tag{17}$$

For m = 1,. . . , 5,

$$V_a^m(\Omega_{iat}) = \begin{cases} \Upsilon^m(\Omega_{iat}) + \delta E_\epsilon[V_{a+1}(\Omega_{i,a+1,t+1})] \ if \ a < 62, \\ \Upsilon^m(\Omega_{iat}) \ if \ a = 62. \end{cases}$$

For m = 6 (two-year college attendance),

$$V_a^6(\Omega_{iat}) = \begin{cases} \Upsilon^6(\Omega_{iat}) + \delta^2 E_\epsilon[V_{a+2}(\Omega_{i,a+2,t+2})], \ 19 \leq a \leq 22. \\ \infty \ \ if \ \ e_{6it} = 1 \ and \ g_{6it} = 0. \end{cases}$$

For m = 7 (Four-year college attendance),

$$V_a^7(\Omega_{iat}) = \begin{cases} \Upsilon^7(\Omega_{iat}) + \delta^4 E_\epsilon[V_{a+4}(\Omega_{i,a+4,t+4})], \ 19 \leq a \leq 22. \\ \infty \ \ if \ \ e_{7it} = 1 \ and \ g_{7it} = 0. \end{cases}$$

where $\Upsilon^m(\Omega_{iat})$ is current utility from an alternative m, δ is the discount factor and Ω_{iat} is a set of state variables of an individual i at age a in year t that includes gender, education level, choice in the previous period, experience accumulated in each sector-occupation, year of birth, current year, indicators for four-year and two-year college enrollment, indicators for four-year and two-year college graduation, individual shocks, current and past technology shocks and current and past skill prices. The discount factor δ is given as 0.95 and it is not estimated. e_{6it} is a dummy variable that is 1 if an individual i once enrolled two-year college, and 0 otherwise. g_{6it} is a dummy variable that is 1 if an individual i complete two-year college degree, and 0 otherwise. e_{7it} is a dummy variable that is 1 if an individual i once enrolled four-year college. g_{7it} is a dummy variable for four-year college graduation. For four-year and two-year college attendees, they are forced to complete their degree without any break. 4(2)-year college freshmen are allowed to make a choice after graduation, which is 4(2) years later from college enrollment. These features are reflected in the time subscript and discount rate in the value functions for four-year and two-year college education.

6.2.2 Wage Determination

The wage level $w^{j,s}_{e,g,t}(\Omega_{iat})$ for a worker i with education level e in age group g, occupation j and sector s is a multiplication of skill price $r^{j,s}_{e,g,t}$ and the amount of human capital $h^{j,s}(\Omega_{iat})$.

$$w^{j,s}_{e,g,t}(\Omega_{iat}) = r^{j,s}_{e,g,t}h^{j,s}(\Omega_{iat}),\ j = W, B,\ s = M, R,\ e = c, h,\ g = 0, 1. \tag{18}$$

Skill prices are determined at the levels by sector, occupation, education (college or high school) and age groups (younger and older). The utilization of human capital is sector-occupation specific. Specifically, I assume the following human capital production function. For workers with high school or lower degrees,

$$\begin{aligned} log[h^{j,s}(\Omega_{iat})] =& \beta^{j,s}_0 + \beta^{j,s}_1 I(Female = 1) + \beta_3(a - 19) + \beta_4(a - 19)^2 \\ &+ \beta_5 Exp^{j,s}_{it} + \beta_6 Exp^{not}_{it} + \beta^{j,s}_7(Yeduc_{it} - 9) + \epsilon^{j,s}_{it} \end{aligned}$$

where $Exp^{j,s}_{it}$ is an experience in current sector-occupation and Exp^{not}_{it} is the sum of experience in all other sector and occupations accumulated until year t. $Yeduc_{it}$ is the years of education and $\epsilon^{j,s}_{it}$ is an individual sector-occupation skill shock. It is assumed that age effect (β_3 and β_4) and experience effect (β_5 and β_6) are the same across difference sector-occupations.

Current utility from work in each sector-occupation is the net of wage and moving cost.

$$\Upsilon^m(\Omega_{iat}) = w^{j,s}_{e,g,t}(\Omega_{iat}) - C_{mm^{-1}},\ m = 1, \ldots, 7 \ and\ m^{-1} = 1, \ldots, 7.$$

where m is a current choice, m^{-1} is a choice in the previous period and $C_{mm^{-1}}$ is a moving cost that occurs when an individual who chose m^{-1} alternative in the previous year choose an alternative m in the current period.

The transition cost $C_{mm^{-1}}$ is assumed to have a following simple structure.

$$C_{mm^{-1}} = \begin{cases} \kappa_1 & \text{if } m > 5 \text{ and } m^{-1} < 5 \\ \kappa_2 & \text{if } m > 5 \text{ and } m^{-1} = 5 \\ \kappa_3 & \text{if } m < 5,\ m^{-1} < 5 \text{ and } m \neq m^{-1} \\ \kappa_4 & \text{if } m = 5 \text{ and } m^{-1} < 5 \\ 0 & \text{otherwise} \end{cases}$$

6.2.3 Home Production

It is assumed that the current utility from home production has a following functional form.

$$\begin{aligned} \Upsilon^5(\Omega_{iat}) = exp(&\varphi_0 + \varphi_1 I(Female = 1) + \varphi_2(age - 19) + \varphi_3(age - 19)^2 + \\ &\varphi_4 I(year \geq 1998) I(Male = 1) + \varphi_5 I(year \geq 1998) I(Female = 1) + \\ &\varphi_6(year - 1961) + \varphi_7 I(year - 1998) I(Male = 1) + \epsilon^h_{it}) + \varphi_8 I(Male = 1) - C_{5,m^{-1}} \end{aligned} \tag{19}$$

The current utility from home production depends on gender, age and time trend. Korea experienced a severe economic crisis in the 1997-98 Asian Financial Crisis. φ_4, φ_5, and φ_7 are parameters to fit decreased employment rate after the crisis. $C_{5,m^{-1}}$ is a moving cost when an individual who chose m^{-1} in the previous year choose to be at home.

6.2.4 Education

Utility from entering two-year college is presented by the following equation. This is the present value of utility for 2 years in college. It depends on gender, age and average personal income per capita in year t, the interaction between gender and the personal income and moving cost. Entering college at age older than 19 generates additional costs such as private education cost and psychic cost by change in peer relationship. Household income also affects the demand for education and it differentially has an effect on males and females.

$$\begin{aligned} \Upsilon^6(\Omega_{iat}) = \theta^0_0 + \theta^0_1 I(Female = 1) + \theta^0_2(age - 19) + \theta^0_3 Income_t + \\ + \theta^0_4 I(Female = 1) Income_t + \epsilon^{E_0}_{it} - C_{6,m^{-1}} \end{aligned}$$

Utility from entering four-year college has a similar functional form with that of entering two-year college. The difference is that this is the present value of utility for 4 years in college.

$$\begin{aligned} \Upsilon^7(\Omega_{iat}) = \theta^1_0 + \theta^1_1 I(Female = 1) + \theta^1_2(age - 19) + \theta^1_3 Income_t + \\ + \theta^1_4 I(Female = 1) Income_t + \epsilon^{E_1}_{it} - C_{7,m^{-1}} \end{aligned}$$

6.2.5 College Application and College Enrollment Quota

As previously mentioned, individuals under age 23 first make a choice on four-year college application according to the values of the seven alternatives. An aggregate number of four-year college applicants in year t is determined by the sum of the individuals who attending four-year college is the best option and previously did not enroll four-year college.

$$Q^D_{mt} = \sum_{a=19}^{22} \sum_{i=1}^{N_{at}} I(M_t = 1) d^m_t(\Omega_{iat}, d^m_{t-1} = 0) \ for \ m = 7$$

where N_{at} is a cohort size for people whose age is a in year t and M_t is an indicator whether an individual is in the military because of the mandatory military service for males in Korea.[31]

If the aggregate number of four-year college applicants is greater than four-year college quota in year t, then only the quota number of applicants can enter four-year college. Otherwise, all the applicants can enter four-year college.

$$Q_{7t} = Q^S_{7t} \ if \ Q^D_{7t} \geq Q^S_{7t}$$
$$Q_{7t} = Q^D_{7t} \ if \ Q^D_{7t} < Q^S_{7t}$$

where Q_{7t} is the number of four-year college entrants and Q^S_{7t} is four-year college quota in year t.

When the number of four-year college applicants is greater than four-year college quota, it is assumed that the actual four-year college entrants are determined by the following score.

$$\Phi_7(\Omega_{iat}) = \phi^1_1 I(Female = 1) + \phi^1_2 Feduc + \phi^1_3 Meduc + \phi^1_4 I(Foccp = 1) + \epsilon^{s7}_t \tag{20}$$

where Feduc is father's education (elementary school or lower, middle school, high school, college or more), Meduc is mother's education (elementary school or lower, middle school, high school or more) and Foccp is father's occupation (white collar or blue collar).

The two-year college admission process proceeds after the completion of four-year college admission process. Only people who previously did not enter two-year college can apply. The number of two-year college applicants is determined by the aggregation of people whose the best alternative is

[31] There is a mandatory military service in South Korea and Korean males without serious health problem should serve in military. The term of military service has decreased since 1968, for example, it was 36 months from 1968 to 1976 and it is now 21 months for the army. I simplify that the term of military service was three years before 1994 and two years since 1994. Table A1 in appendix F reports the exact term of military service by year and position. Males can choose the approximate timing when they start to serve in military if they are older than 19 and younger than the age upper bound, which also has been changed, however most people finish their mandatory military service before 25. Males should continuously provide military service until finishing the term of military service if serious health problem does not occur in military. Because of the mandatory military service, most Korean males halt college education in the middle of it and they tend to enter labor market 2-4 years later than females. I do not model the military entry choice but I consider it when I calculate the aggregate labor supply. I assume that it is determined exogenously depending on age differentially by education level at age 19.

entering two-year college and those who fail to enter four-year college and entering two-year college is the second-best option.

$$Q^D_{mt} = \sum_{a=19}^{22} \sum_{i=1}^{N_{at}} I(M_t = 1) d^m(\Omega_{iat}, d^m_{t-1} = 0, \widehat{d^7_t} = 0) \ for \ m = 6.$$

where $\widehat{d^7_t}$ a dummy variable that indicates four-year college matriculation in year t.

If the number of two-year college applicants is greater than two-year college quota, only the two-year college quota amount of applicants can enter two-year college.

$$Q_{6t} = Q^S_{6t} \ if \ Q^D_{6t} \geq Q^S_{6t}$$
$$Q_{6t} = Q^D_{6t} \ if \ Q^D_{6t} < Q^S_{6t}$$

where Q_{6t} is the number of two-year college entrants and Q^S_{6t} is two-year college quota in year t.

In that case, two-year college entrants are determined according to the following score.

$$\Phi_6(\Omega_{iat}) = \phi^2_1 I(Female = 1) + \phi^2_2 Feduc + \phi^2_3 Meduc + \phi^2_4 I(Foccp = 1) + \epsilon^{s6}_t \tag{21}$$

People who do not enter four-year college or two-year college choose an alternative among the remaining five alternatives.

6.3 Market Clearing Condition

Aggregate labor supply in sector s, occupation j, education group e and age group g is the sum of human capital provided by workers in the group.

$$S^{j,s}_{e,g,t} = \sum_{\{a:g(a)=g\}} \sum_{i=1}^{N_{at}} I(e(i) = e) I(M_t = 1) h^{j,s}(\Omega_{iat}) d^{m(j,s)}_t(\Omega_{iat}), \ s = M, R, \ j = W, B, \ e = c, h, \ g = 0, 1.$$

Market equilibrium conditions are

$$r^{j,s}_{e,g,t} = \frac{\partial Y^j_t(S^{w,s}_t, S^{b,s}_t, K^j_t)}{\partial S^{j,s}_{e,g,t}}, \ for \ s = M, R, \ j = w, b, \ e = c, h, \ g = 0, 1. \tag{22}$$

$$[S^{j,s}_{e,g,t}]_{Demand} = [S^{j,s}_{e,g,t}]_{Supply} \ for \ s = M, R, \ j = w, b, \ e = c, h, \ g = 0, 1. \tag{23}$$

$$K^M_t = \overline{K^M_t}, K^R_t = \overline{K^R_t} \tag{24}$$

The equation (23) presents that the aggregate human capital demand for each group is determined at the level that makes the marginal value product of each human capital be equal to its skill price. It is assumed that physical capital is exogenously supplied at the level that is same with data.

Because it is not possible to find an analytical solution for equilibrium skill prices that satisfy the above market clearing conditions, this study assumes that the skill prices are approximated by the following way (Lee and Wolpin 2006).

$$lnr^{j,s}_{e,g,t+1} - lnr^{j,s}_{e,g,t} = \mu_0 + \sum_{k(j,s,e,g)} \mu_{k(j,s,e,g)}(lnr^{j,s}_{e,g,t} - lnr^{j,s}_{e,g,t-1}) + \sum_{k(s)} \mu_{k(s)}(lnz^s_{t+1} - lnz^s_t) \quad (25)$$

$$for\ s = M, R,\ j = w, b,\ e = 0, 1,\ g = 0, 1.$$

It is assumed that individuals also predict the evolution of the skill prices by the above equation.

7 Estimation

7.1 Estimation Method

The simulated method of moments (SMM) is employed as an estimation method in this study. This method finds a set of parameter values that minimizes a weighted sum of distances between data moments and moments simulated by the model. The moments that are considered important to summarize the changes in educational attainment and labor market structure are selected for the estimation.

One thousand five hundred people are randomly extracted from 1% census data for each birth cohort, with their demographic and work information. The economy begins in 1961. People start to make a decision at age 19 and exit from the labor market after making a decision at age 62. I extract information on gender, education at age 18, parents' education and father's occupation from the quinquennial 1% census 1960-2010. For people born before 1942, they start to make a decision in 1961 and their age is older than 19 in that year. I additionally extract information on their choice in 1960 and construct their work experience from the 1960 census. This study simulates the model with these initial conditions and generates simulation moments by weighting cohort size to the choices by the sample individuals in the model.[32]

This study obtains target moments for education, wage, and employment from various data sets. These are summarized below.

1. Education

    - The demand for college education (Data source: Education Statistics, KICE and old news papers)
        - The number of four-year college applicants by year (1969-2014)
        - The number of four-year college applicants from high school graduates (college re-applicants) by year (1972-2014)

[32] The detailed explanation on the estimation procedure is provided in Appendix H

    - The numbers of four-year college applicants by year and gender (1994-2014)
- EAPS: The proportions of people with four-year college and two-year college education at age 30 by each school cohort and gender for the years 1986-2014, respectively
- KLIPS: The ratio of people with each educational attainment by gender and family background (parents' educational attainment and father's occupation)

2. Wage

    - OWS
        - 10th, 50th, 90th percentile log hourly wages by year and gender
        - The mean log hourly wage by year and gender
        - The mean log hourly wage by year, four sector-occupations and gender
        - The mean log hourly wage by year, four education groups and gender
        - The mean log hourly wage by year, four sector-occupations and four education groups
        - The mean log hourly wage by year, college degree and gender
        - The mean log hourly wage by year and four age groups
    - KLIPS
        - The mean log hourly wage by year, work experience (for both current job and the sum of others) and fours sector-occupations
        - The mean wage changes after job transitions by year and current sector-occupation

3. Employment

    - EAPS
        - The proportion of individuals who choose each of the seven alternatives by year and gender
        - The proportion of individuals who choose each of the seven alternatives by year and four age groups
        - The proportion of individuals who choose each of the five work-home alternatives by year and four education groups
    - KLIPS
        - The mean experience by year, age, gender and four sector-occupations
        - One period joint transitions by year
        - One period joint transitions by age

7.2 Identification

There are 88 parameters to be estimated in the model. I briefly explain how the parameters are identified from variations in data moments and functional form assumptions. Human capital production parameters are identified by functional form assumptions and exclusion restriction. An exclusion restriction for the identification of human capital production parameters is a variable that affects current choice of individuals but does not directly affect wage offers. The choice in the previous period works as an exclusion restriction as it affects current choice by generating a different moving cost by current choice but it is not included in the human capital production function.

The preference parameters on work in each-sector occupation and home production parameters are identified by choice moments by demographics and year. The wage difference by sector-occupation cannot fully explain the difference in the proportion of employment in each sector-occupation. The discrepancy identifies the preference parameters on each sector-occupation. The moving cost parameters are identified by transition rate moments. The parameters related to college application choice are identified by variation in the proportion of college applicants by year and demographics. The sector-occupation specific work experience and years of education are exclusion restrictions for the identification of these parameters as they affects wage offers and do not directly affect utility from each choice.

The parameters of production technology are identified by functional form assumption on the time trend of factor intensity parameters and variations in college enrollment quota and cohort size. The elasticity of substitution between college and high school workers is identified by variation in population size and aggregate college quota for working age group in each year. The elasticity of substitution between younger and older workers is identified by variations in cohort size and college enrollment quota for each birth cohort. For example, the relative supply of younger workers to older workers within college-educated worker group varies because of difference in college enrollment quota by birth cohort. The quota for the oldest workers and that for the youngest workers are different so that the labor market entry of the youngest and the exit of the oldest in the next period generate the variation in the relative supply. The change in the relative wage induced by the variation in the relative supply make us identify the substitution parameter. The changes in demographics, college enrollment quota and the assumed exogenous variation in physical capital stock identify parameters for the elasticity of substitution between white-collar workers and physical capital and that between the composite of white-collar workers and physical capital and blue-collar workers.

8 Estimation Result

8.1 Parameter Estimates of the Equilibrium Model

Table 9 presents the estimated parameters by the simulated method of moments. Panel (a) of Table 9 shows the estimates for factor intensity parameters. The positive value of α_{11}^M estimate shows that the marginal product of blue collar skill in manufacturing sector was increasing during the years 1961-1991 while the negative estimate of α_{12}^M presents that the marginal product was decreasing after 1991. The positive estimates of α_{2t}^M and α_{2t}^R imply that the marginal product of physical capital was decreasing for the years 1961-2014 in both sectors. The positive values of $(1-\alpha_{1t}^M)\alpha_{2t}^M$ and $(1-\alpha_{1t}^R)\alpha_{2t}^R$ indicate that the marginal product of white collar skill in both sectors was increasing during the sample period. The estimated factor intensity parameters, therefore, partly explain the increasing average wage of workers in all sector-occupations during the sample period. The estimated parameters also show that the marginal product of white collar skill was increasing more rapidly after 1991, especially in service sector. The negative estimates of α_{31} and α_{32} show the skill biased technical change toward college workers. While it is negligible before the year 1992, the technical progress that raises the relative demand for college workers is evident after the year 1991. This is consistent with the regression results. The negative estimates of α_{41} and α_{42} present that the relative demand for experienced workers increased during the year 1961-2014 while the magnitude is small.

Panel (b) of Table 9 reports the estimates for the elasticity of substitution parameters. The estimate for the elasticity of substitution between blue collar and white-capital composite is 2.927. The elasticity of substitution between white collar and physical capital is estimated to be 2.357. These estimates are substantially greater than the estimates in the previous literature (Krusell et al. 2000, Lee and Wolpin 2006, Johnson and Keane 2013). These estimates show that there exists higher complementarity between physical capital and white collar skill than that between capital and blue collar skill. The estimated elasticity of substitution between high school and college workers is 2.071, which is in the range of the IV estimates and it is comparable to the estimates in the previous literature. The elasticity of substitution between younger and older workers is estimated to be 11.76 and this is also within the range of the IV estimates.

The estimates for home production parameters (or home preference parameters) are presented in panel (c) of Table 9 and they show that females are more productive at home than males (or they prefer to stay at home than males). This partly explains the high ratio of females at home in data. The productivity at home has an inversed U-shape age profile ($\varphi_2 < 0$, $\varphi_3 > 0$). The productivity of home production has also increased over the sample period ($\varphi_6 > 0$). The positive values of φ_4 and φ_5 are consistent with the rapid increase in the proportion of home sector in the East Asian Economic Crisis in 1997-1998 and its persistence after the crisis.

The estimates for parameters of human capital production function reported in panel (e) present that males have more human capital ($\beta_1^{s,j} > 0$) than females in all sector-occupations. It has an inversed U-shape age profile ($\beta_2 > 0, \beta_3 < 0$). The accumulated experience in current sector-occupation is more productive that experience accumulated in other sector-occupation but experience in other sector-occupation is barely productive in the current sector-occupation (β_5, β_6). Education increases human capital more in white collar occupations ($\beta_7^{s,j}$) in both sectors.

The estimates for parameters related to the demand for four-year college education are shown in panel (f). θ_0^0, which can be interpreted as a net present value of tuition and psychic cost for 4 years in four-year college, is estimated to be -385287.5. Females have an additional cost for four-year college education ($\theta_1^0 < 0$) and re-applying for college also generates an additional cost ($\theta_1^0 < 0$). As household income grows, the demand for four-year college increases ($\theta_3^0 > 0$) and the income effect is greater for females ($\theta_4^0 > 0$). For two-year college, the net present value of tuition and psychic cost is lower than that of four-year college (θ_0^1=-101910.0). Females also have higher cost for two-year college education ($\theta_1^1 < 0$) and re-applying for two-year college generates a large cost (θ_2^1). The demand for two-year college also grows as household income increases for males ($\theta_3^1 > 0$).

Panel (h) of Table 9 reports the utility cost from working in each sector-occupation and they show that both males and females have higher utility cost from working in white collar occupations for both sectors. In the estimated model, wage is higher in white collar occupation than in blue collar occupation in general so that higher utility cost working in white collar occupations helps fit the significant employment rates in blue collar occupations. The moving cost parameters are presented in panel (i) of Table 9. The estimate for κ_1 is 964817.2 and this implies that moving from work to college generates a large cost. The estimate for κ_3 is 257002.3 and this implies that job transition to a new sector-occupation that is different from the previous sector-occupation generates a significant cost. The estimate for κ_4 is an estimated cost for moving from home to work and it is 8943.3. κ_2 represents a moving cost from home to college and the positive estimate implies that home is a better place to prepare for college entrance compared to transition from two-year college to four-year college.

8.2 Model Fit

Figure 13 evaluates model fits by comparing wage, employment and education moments from simulation and data. Panel (a) of Figure 13 depicts the simulated and data moments for changes in the relative wage of college workers to high school workers. The simulated moments fit the actual data well. They reproduce the declining college wage premium before the early 1990s and the stable wage gap after the early 1990s. Before the early 1990s, the increasing relative supply of college workers shapes the decreases in the college wage premium. The increase in relative demand by technical changes stops a further decrease in the college wage premium after the early 1990s.

Panel (b) of Figure 13 describes the changes in the 90th, 50th, and 10th percentile wages from data and simulation. The model fits the overall levels of percentile wages and the rising trends of them well. Panel (c) of Figure 13 shows the simulated and data moments for changes in the 90-10 percentile and the 90-50 wage gaps, respectively. The simulated 90-10 wage gap fits the trend in data that the 90-10 wage gap decreases from 1980 to the early 1990s and then increases after the early 1990s. The simulated 90-10 wage gap, however, moves more smoothly so that it does not generate sharp changes in the wage gap in data. The simulated 90-50 wage gap also emulates the changing patterns in data that the gap decreases from 1980 to the early 1990s and then increases. It emulates the wage gap in data very well after the early 1990s but underpredicts the wage gap before the early 1990s.

Panel (d) of Figure 13 shows the changes in the mean wage for males and females from data and the model. It reasonably fits the overall increasing trends of the mean wages and their levels. Panel (e) of Figure 13 depicts the changes in the proportion of service sector workers to population size from the simulation and data, respectively. Even though the model overpredicts the proportion of service sector workers before the late 1990s, it fits the data very well after the late 1990s. Panel (f) of Figure 13 shows the proportions of white-collar workers to population size from the simulation and data. The model fits the overall level and rising trend of the proportion of white-collar workers, although the model simulation slightly overestimates the ratio before the early 1990s and underestimates it after the early 2000s. Panel (g) of Figure 13 presents the proportion of home sector by gender from the simulation and data. The simulated results imitate the ratio in the data very well.

Panel (h) of Figure 13 depicts the changes in the number of four-year college applicants. The model simulation generally reproduces the actual number of four-year college applicants quite well. The number of four-year college applicants by the model simulation is greater than that from data before the mid-1990s. The model emulates the four-year college enrollment rate in the data quite well, even though the enrollment rate from the model is slightly lower than the actual enrollment rate (Panel (i) of Figure 13). This may be because the model sets a restriction that only allows people to enroll in four-year college by age 22, while a small fraction of people still enroll in four-year college after age 22 in the data. Some miscellaneous four-year colleges not included in the calculation of the four-year college quota may also be a reason for the gap. Panel (j) of Figure 13 describes two-year college entrance rates from the model simulation and data. The model fits the actual two-year college enrollment rate for cohorts who were born before 1970 quite well but it overpredicts the two-year college enrollment rate for cohorts born after 1973.

9 Counterfactual Experiments

9.1 Experiment I: Manipulation of College Enrollment Policy

Using the estimated model, this study conducts counterfactual experiments that manipulate the college enrollment quota. Even though there are many possible manipulations of college quota, this study experiments with two cases: (1) four- and two-year college quotas have been set at the historical level of four-year and two-year college completion rates in the US, respectively, and (2) there is no college quota and every college applicant enters college.[33] Figure 14 compares the key moments from the baseline model and two counterfactual experiments.

Panel (a) of Figure 14 presents four-year college enrollment rates in the baseline model and the two counterfactuals for 1950-1984 birth cohorts. It shows that the four-year college enrollment rate increases substantially when the college quota is abolished and every college applicant enrolls in college. The average difference in four-year college enrollment rates between the baseline model and the second counterfactual (no college quota) is about 19.1 percentage points. In the counterfactual experiment with the US college graduation rate level quota, the four-year college enrollment rate is higher in the counterfactual than in the base model for birth cohorts born before 1975 but is lower for cohorts born after 1975.

Panel (b) of Figure 14 shows the number of four-year college applicants in the baseline model and the counterfactuals. The number of four-year college applicants is significantly lower in the counterfactual without a college quota than the baseline model in all sample periods. This is related to the lowered college wage premium because of the increase in the college enrollment rate under the counterfactual policy (Panel (b) and (d) of Figure 14). Although the number of four-year college applicants is reduced in this counterfactual, the four-year college enrollment rate is much higher because the gap between the number of four-year college applicants and the four-year college quota is very large in the baseline model (and data) so that the number of four-year college applicants in the counterfactual is even still higher than the quota. The number of four-year college applicants is slightly lower in the counterfactual with the U.S. level quota than in the base model before the mid-1990s but is significantly greater after the mid-1990s. For the school cohorts who are supposed to enter college after the mid-1990s, their four-year college quota is significantly lower than the quota in the baseline model so that people in the counterfactual world expect that the supply of college workers does not increase rapidly and the college wage premium goes up more rapidly compared to the baseline model. This incentivizes them to apply more. Panel (c) of Figure 14 shows the two-year college enrollment rates. The two-year college enrollment rate is higher for the 1964-1973 birth cohorts in the counterfactual without a college quota than in the baseline model, while it is substantially lower in the counterfactual for the 1974-1984 birth cohorts. It is the lowest in the counterfactual with the US level quota in most sample periods.

Panel (d) of Figure 14 presents the changes in the college wage premium from the baseline model and the two counterfactual experiments. This shows that the college enrollment quota plays an important role in shaping changes in the college wage premium. Firstly, the college wage premium is significantly lower in the counterfactual with the US level quota than in the base model in all

[33] As the economy begins in 1961, educational attainment of people who were older than age 22 in 1961 is set at the level in the census data and this is given as an initial condition. It is also fixed at the level in the counterfactuals.

the sample periods, while the gap narrows over time as educational attainment becomes lower for recent cohorts in the counterfactual than in the baseline model. The college wage premium in the base model is 205% in 1980 and it is 151% in the counterfactual. The difference in the college wage premium between the base model and the counterfactual becomes negligible in 2014. Under the policy scenario that every applicant can enter college, the college wage premium is much lower than those from the baseline model simulation and the counterfactual with the US level quota. The college wage premium in 1980 is 132% in this experiment and becomes 16.0% in 2014 in the counterfactual without the college quota. The college wage premium in 1980 is still high in the counterfactual without the college quota because high school graduation rate given in the initial condition is much lower for older cohorts, thus college application is restrained by it and the influx of college-educated workers is also restrictive in the early period.[34]

Panel (e) of Figure 14 shows the 90-10 wage gap in the counterfactual experiments. Before the late 1990s, the 90-10 wage gaps in all three scenarios are not much different from each other. After the late 1990s, the 90-10 wage gap in the counterfactual without a quota becomes substantially lower than that in the baseline model and that in the counterfactual with a US level quota. The 90-10 wage gap in the counterfactual that the college quota is determined at US college completion level is lower than that in the baseline model in most years before 2009, and the gap is reversed from 2009. On the other hand, the 90-10 gap in the counterfactual with no quota is substantially lower than that in the other two cases after 2000. Panel (f) of Figure 14 presents the 90-50 wage gaps in the baseline model and the counterfactuals. The gap is slightly lower in the counterfactual with the US level quota than in the base model before 2009, but the gap is reversed after 2009. The 90-50 is lowest in the counterfactual without a college quota in most years, especially after the late 1990s. Panel (g) of Figure 14 depicts the 50-10 wage gaps. The wage gap is not much different among the three scenarios and the gap is slightly greater in the counterfactual without a college quota.

Panel (h) of Figure 14 presents the proportion of home sector in each scenario. The proportion of home sector in the scenario with the US level quota policy is lower than that in the baseline model before the late 1990s, and it becomes substantially greater after the late 1990s. The proportion of home sector is significantly lower in the regime with full supply of college education than the other two cases. This is partly explained by the mechanisms that the ratio of home sector is reduced when more people enter college or choose to work in the sector-occupations because of the increase in human capital through college education. Panel (i) of Figure 14 presents the proportion of service sector to population, and the figure shows that the proportions of people who choose to work in the service sector in the two counterfactuals are generally greater than that in the baseline model. Panel (j) of Figure 14 shows the proportion of people who work in white-collar occupations

[34] The education level of people who were older than age 22 in 1961 is also fixed at the level given in data. This is another restriction.

to population, and this is also greater in the counterfactuals.

9.2 Experiment II: No Technical Change Biased to College Workers

In the previous subsection, we explore the importance of the relative supply of college educated workers to high school workers on the changes in educational attainment and labor market structure. This subsection explores the importance of demand factors for the changes in the labor market structure focusing on the role of technical change biased to college educated workers. This study conducts a counterfactual experiment that examines what would happen in the labor market if there was no technical change biased to college workers, which means the factor intensity parameter on the aggregate supply of high school and college workers in each sector-occupation is fixed at 1961 level ($\alpha_{31} = 0$ *and* $\alpha_{32} = 0$). Figure 15 reports the counterfactual experiment results and compares them with moments generated from the baseline model.

Panel (a) of Figure 15 shows the changing patterns of college wage premium for the years 1980-2014 in the baseline model and the counterfactual. The college wage premium is lower in the counterfactual in the the sample periods but the gap between college premiums in the base model and the counterfactual is small before the early 1990s. The difference expands after the early 1990s. This is because technical progress biased to college workers was small before the early 1990s as seen in the parameter estimate and there was an acceleration in the technical progress after the early 1990s. This graph shows that technical progress biased to college workers has importantly affected the college wage premium in Korea.

Panel (b) of Figure 15 presents the number of four-year college applicants and it shows that there is a significant reduction in the number of four-year college applicants after the mid 1980s. Since the technical progress biased to college workers is small in the baseline model, the difference between the baseline model and the counterfactual is not large in the earlier periods. As perfect foresight is assumed in the model, students who graduate after the mid 1980s expect that there will be a substantial increase in college wage premium after their college graduation so that they apply for college more under this expectation in the baseline model with a structural break in technical progress in the early 1990s. Even though there is a decrease in the number of four-year college applicants in the counterfactual, it is still above the four-year college quota and four-year college enrollment rate is barely changed compared to that in the baseline model (Panel (c) of Figure 15). Panel (d) of Figure 15 describes two-year college enrollment rates in the baseline model and the counterfactual. The two-year college enrollment rate is slightly higher for 1951-1972 cohorts and is substantially lower for 1974-1984 cohorts in the counterfactual than in the baseline model.

Panel (e) of Figure 15 shows the 90-10 wage gap. Before the early 1990s, the 90-10 wage gap is quite similar between the baseline model and the counterfactual. The 90-10 wage gap is even smaller in the counterfactual after the late 1990s. For example, the ratio of the 90th percentile wage to the 10th percentile wage is 3.68 in 2014 while it is 4.67 in the baseline model. This implies that the accelerated technical progress biased to college workers after the early 1990s accounts for a significant portion of the rising wage gap between the 90th percentile wage and the 10th percentile wage after the early 1990s. Panel (f) of Figure 15 presents the 90-50 wage gap. The gap is slightly greater in the counterfactual than in the baseline model before the late 1990s while it is much smaller in the counterfactual after the late 1990s. The 50-10 wage gap is depicted in Panel (g) of Figure 15 and the 50-10 wage gap is significantly lower in the counterfactual than the baseline model. In 2014, the ratio of the 50th percentile wage to the 10th percentile wage is 1.82 in the counterfactual and it is 2.01 in the baseline model. The counterfactual experiment that there is no technical progress biased toward college workers shows that the accelerated technological change biased to college workers after the early 1990s significantly contributes to the increase in wage inequality after the early 1990s. Panel (h) of Figure 15 shows that there is not much difference in employment rate between the baseline model and the counterfactual over the sample periods. The composition in the workplace, however, is substantially changed in the counterfactual without the technical change. Panel (i) of Figure 15 presents that the proportion of service sector workers is significantly reduced in the world without technical progress biased to college-educated workers. Panel (j) of Figure 15 shows that the proportion of white-collar workers is substantially lower in the counterfactual.

10 Conclusion

Educational attainment has increased dramatically in Korea over the past 60 years. The college enrollment rate was below 10% in the 1960s, and now approaches 90%. Changes in the labor market structure have also been substantial. Wage inequality in its various dimensions decreased rapidly between 1980 and the early 1990s and increased from the early 1990s to the late 2000s. The proportions of service sector workers and white-collar workers in the labor market have also increased during the past 30 years. This study relates these changes together and analyzes the phenomena synthetically. This study first investigates the causal effect of the change in the overall educational level of workers on wage structure, exploiting the College Enrollment Quota Policy as a policy experiment that generates exogenous variations in educational attainment. The detailed underlying mechanisms and their interactions are explored through a dynamic equilibrium model.

This study first analyzes the impact of the relative supply of college-educated workers to high school-educated workers on the relative wage of college workers using the proportion of college-educated workers predicted by the college quota, and cohort size as an instrument. The estimated results show that college and high school workers are imperfectly substitutable. The demand trend that has increased the college wage premium is also found. The changes in the relative supply and relative demand explain the changes in the relative wage in Korea over the past 35 years very well. This study also estimates the effect of differential growth in educational attainment by age group on differential changes in the relative wage across age groups using the IV regression. It is estimated that different age groups are imperfectly substitutable. The differential changes in the relative wage across different age groups are well explained by the differential growth in the relative supply and demand trend.

This study develops and estimates a dynamic equilibrium model with two-sector-two-occupation, overlapping generations and individuals with heterogeneous skills. The main goal of building the equilibrium model is to explain the increases in educational attainment and college application and the changes in wage and employment structure simultaneously. We also explain the changes in wage and employment structure in their more detailed dimensions. The model contains important features in the college application and admission system in Korea, including the College Enrollment Quota Policy. Ex-post college enrollment is distinguished from ex-ante college application. In the model, the number of college-educated people in the economy is exogenously determined by the college quota when the quota is binding: the number of college applicants is greater than the quota. The structure of production technology is based partly on the IV regressions results. Technology is allowed to change and is represented by time-varying factor intensity parameters. Individuals are heterogeneous by their demographics and unobservable shocks. They make choices based on their preferences, skill endowments, and current and expected future skill prices. The equilibrium skill prices are determined at the marginal value product in the competitive market.

The estimated model fits key education, wage, and employment moments well. It is exploited to conduct several counterfactual experiments. This study first investigates the effect of the overall educational attainment of workers on wage structure by manipulating the college quota level variously. When there is no college quota and all college applicants can enter college, the four-year college enrollment rate increases significantly, while the number of four-year college applicants is reduced. The college wage premium is substantially reduced and the percentile wage gaps decrease modestly. This study also assesses the importance of technical progress biased to college workers to account for the changes in wage structure from a counterfactual experiment that assumes there was no technical change biased to college workers. The result shows that technical progress biased toward college workers has played an important role for the rising inequality measured by the percentile wage gaps and the stable college wage premium after the early 1990s even though the rapid increase in supply of college-educated workers. The college application and enrollment rates have increased because the college wage premium barely falls. The increase in demand for college workers has been the impetus for the sustained increase in college enrollment rate and the continued increase in college enrollment rate has restrained the increase in college wage premium.

A limitation of this study is that it does not incorporate possible changes in average quality of college workers and high school workers occurring as the proportion of college workers expands. This study implicitly assumes that the ability of an individual at age 19 that may be partly measured by a college entrance exam score is barely related to future labor market outcomes. In this study, the exam score is approximated by gender and family background and only gender is related to human capital used in the labor market. If we allow for heterogeneous ability at 19, which is related to both exam score and future wage, then the increase in college-educated workers accompanying an increase in college quota can accompany the change in the average ability of college workers. If this is the case, the relationship between the relative supply and the relative wage can be estimated differently when the quality effect is incorporated in the model.

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Figure 1: The Changes in Educational Attainment in South Korea measured at age 35, 1920-1989 Birth Cohort

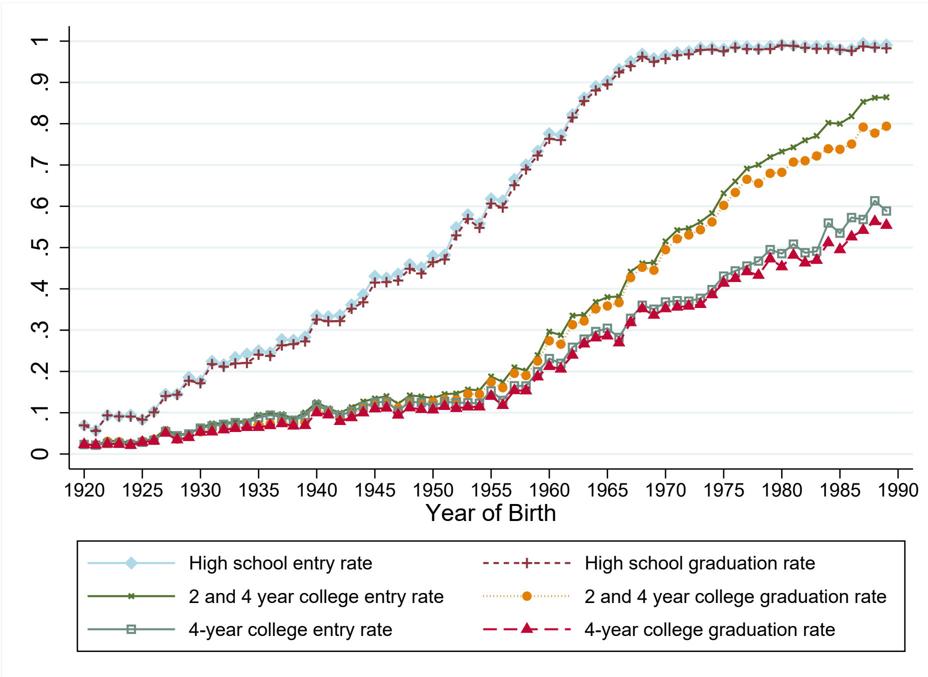


Figure 2: 4-year college application rate by age and 4-year college entrance rate measured at age 35 by Birth Cohort

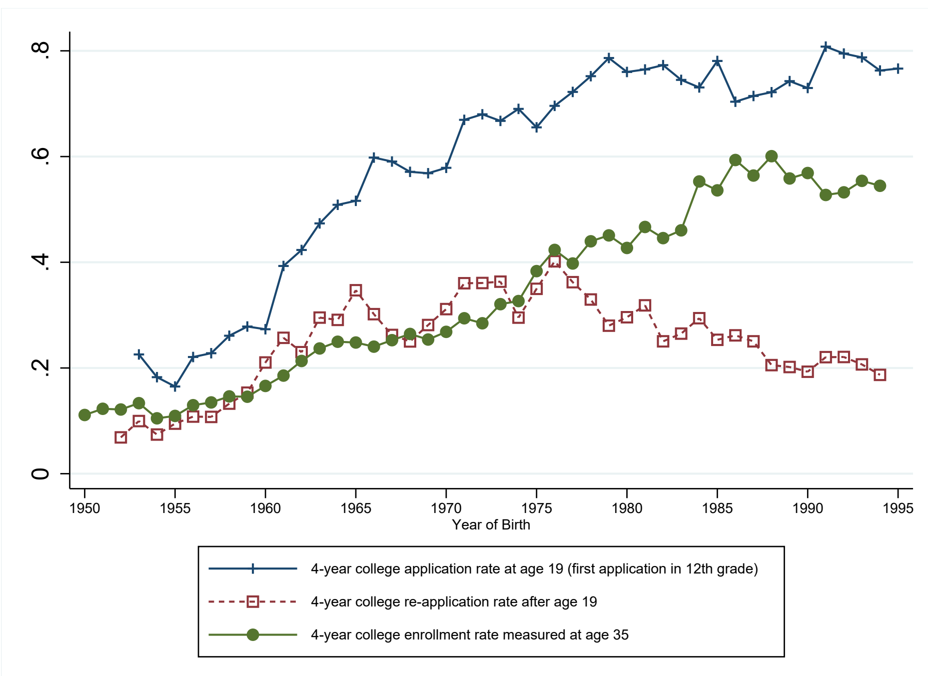


Figure 3: The Changes in Wage Inequality, 1980-2014: Percentile Wage Gaps

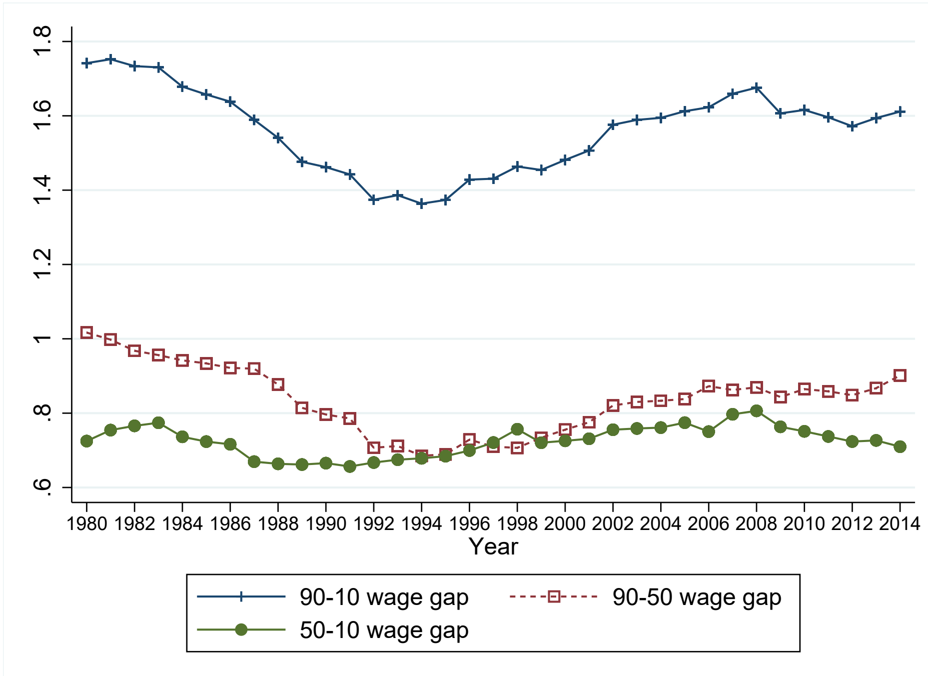


Figure 4: The Relative Wage and the Relative Labor Supply of College Workers to High School Workers

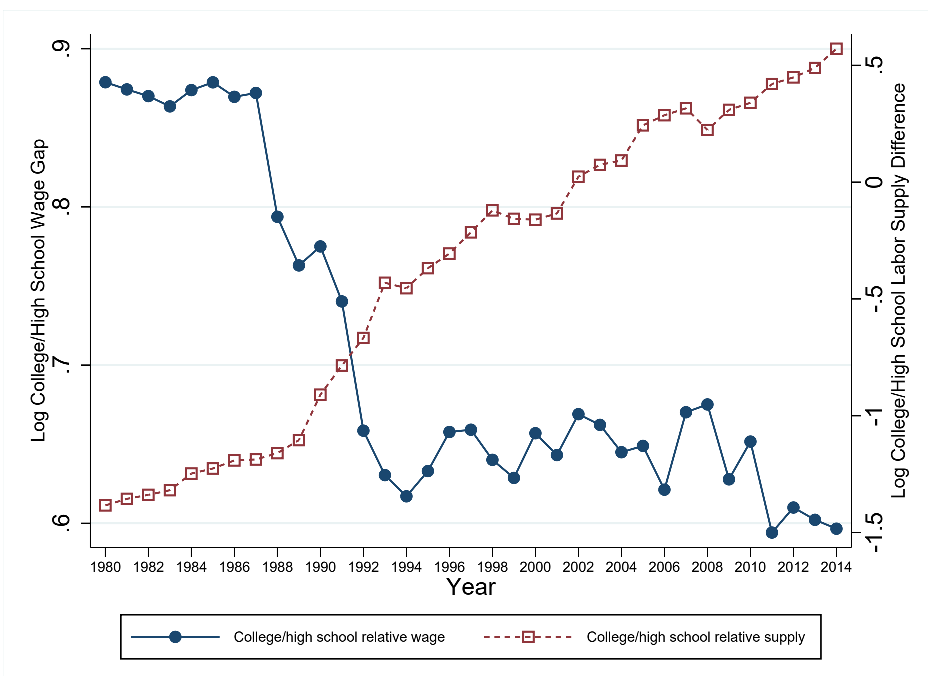
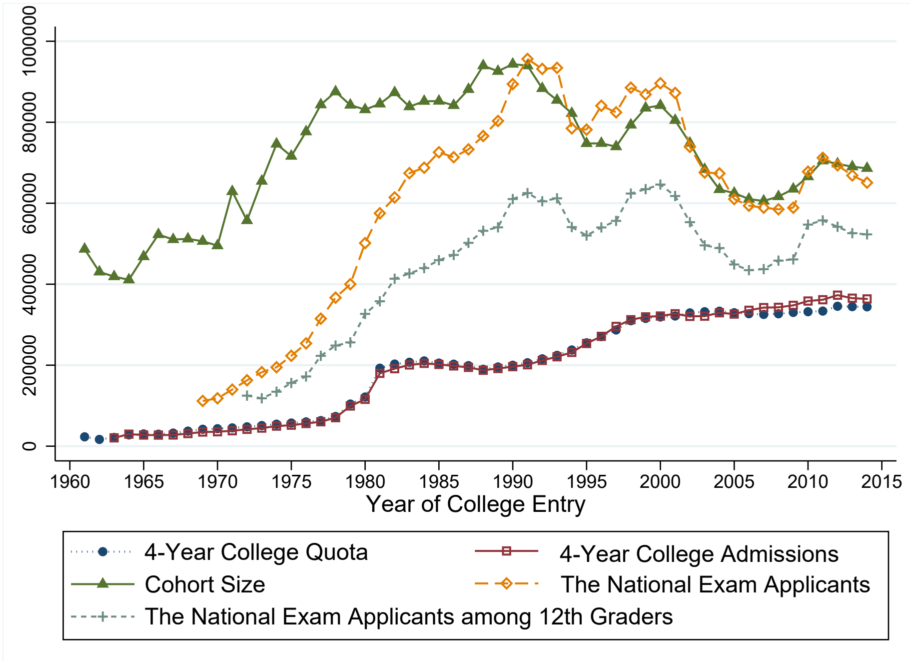
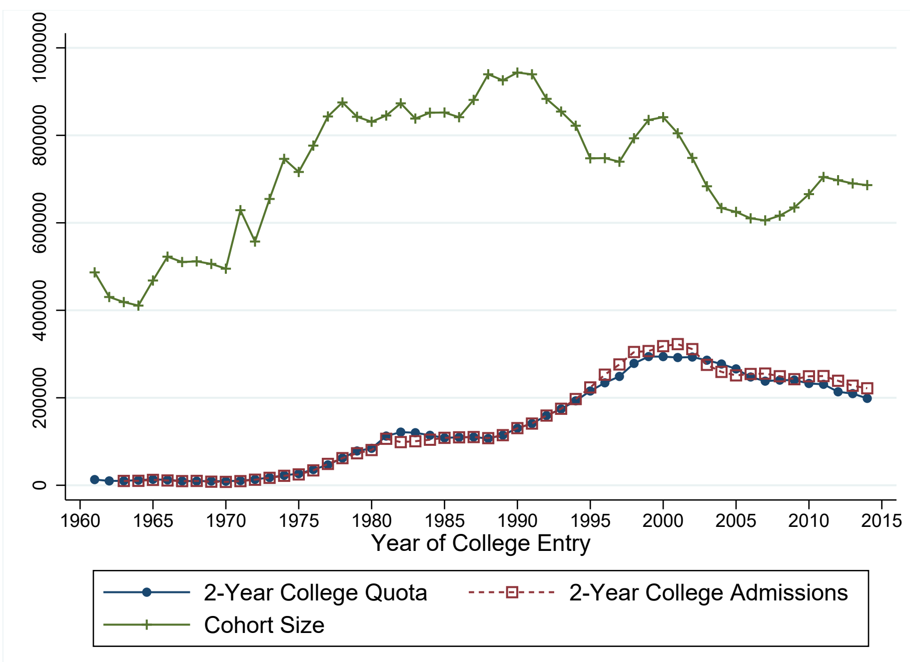


Figure 5: College Quota, Application and Admission in Korea: 1960-2014

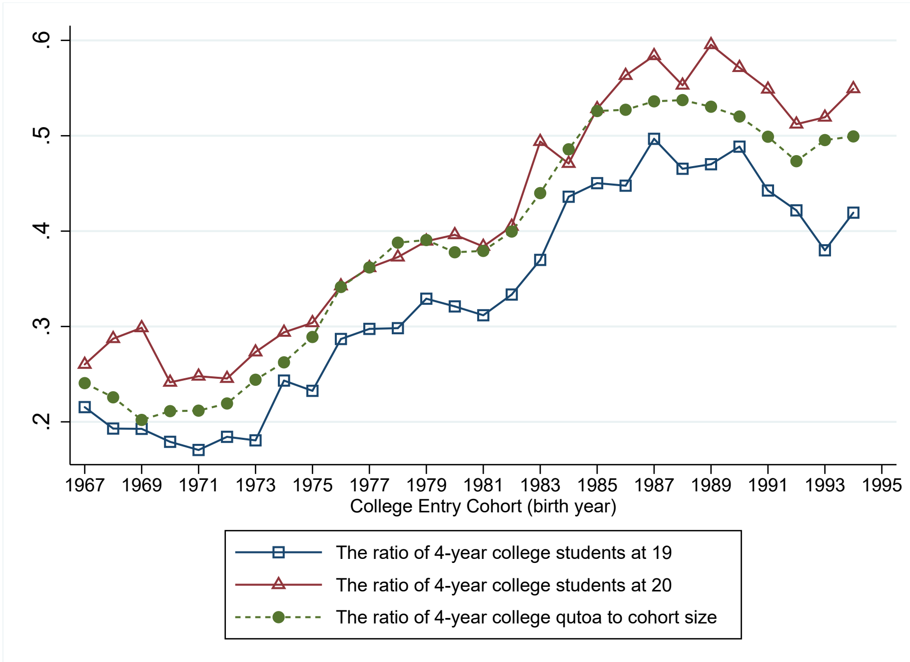


(a) 4-year College Quota, 4-year College Admissions, 4-year College Applicants and Cohort Size: 1960-2014 Birth Cohort

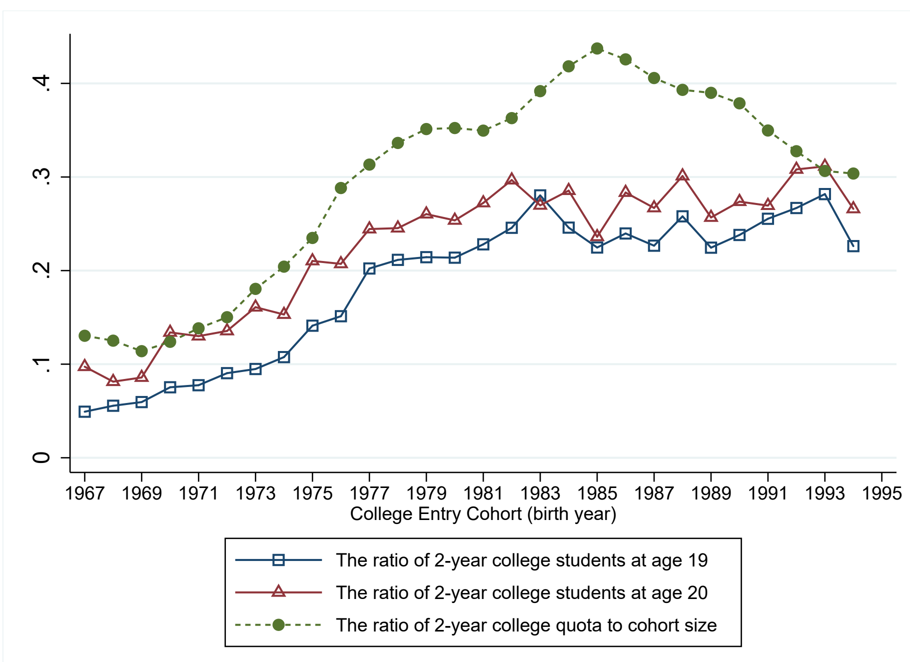


(b) 2-year College Quota, 2-year College Admissions and Cohort Size: 1960-2014 Birth Cohort

Figure 6: The College Enrollment Rates Predicted by College Quota and Cohort Size by Age and the Actual College Enrollment Rate: Four-year and Two-year Colleges



(a) 4-year College Enrollment Rate by Age and Predicted 4-year College Enrollment Rate by Quota and Cohort Size



(b) 2-year College Enrollment Rate by Age and Predicted 2-year College Enrollment Rate by Quota and Cohort Size

Figure 7: The Detrended Relative Wage and the Detrended Labor Supply of College Workers to High School Workers

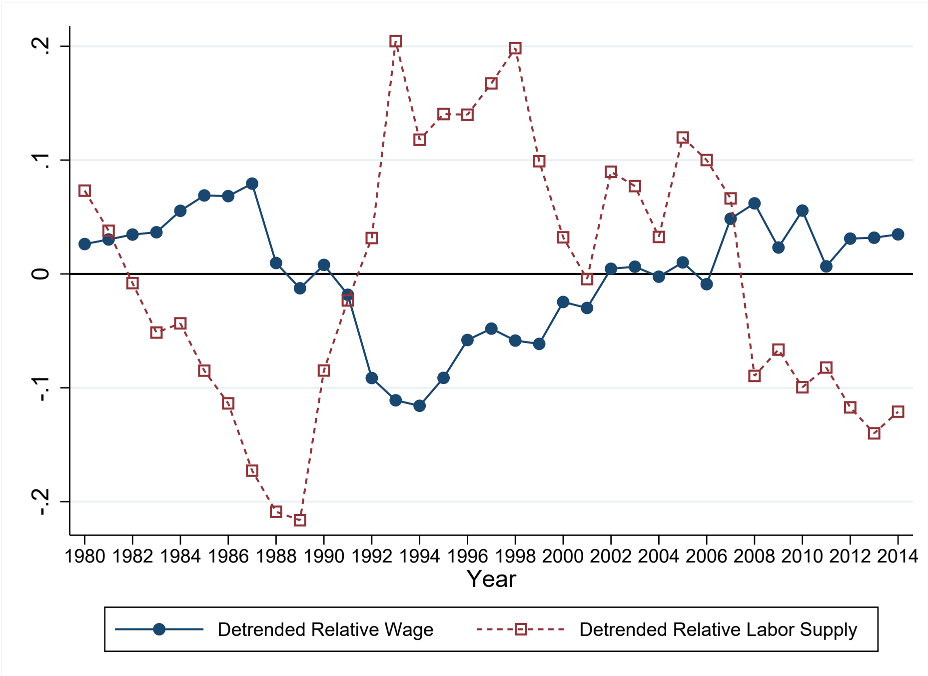


Figure 8: First Stage Relationship: The Detrended Actual Relative Labor Supply and the Detrended Expected Relative Labor Supply of College Workers to High School Workers

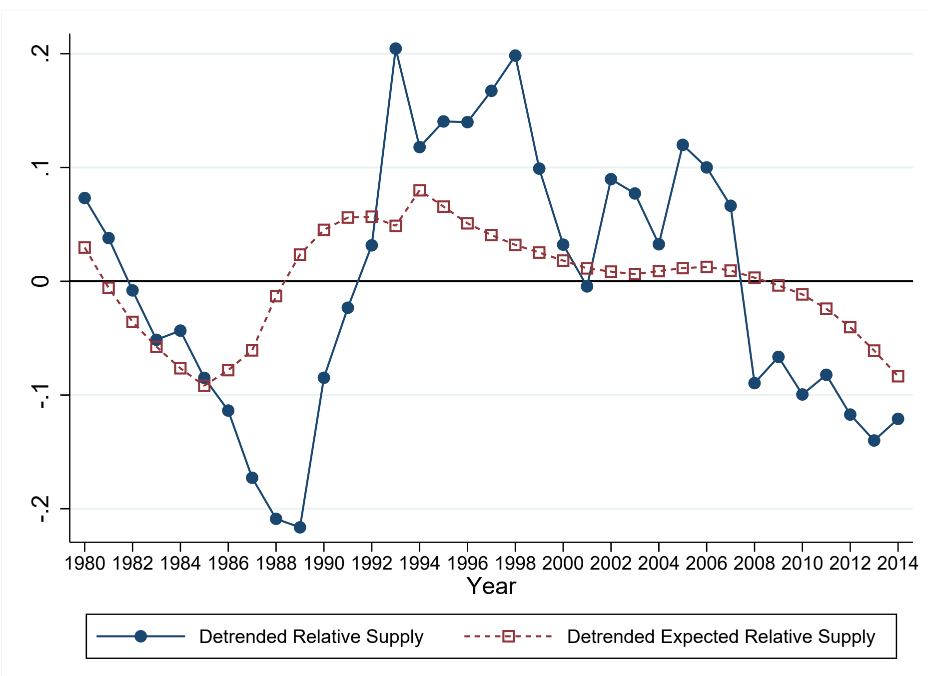


Figure 9: Reduced Form Relationship: The Detrended Relative Wage and the Detrended Expected Labor Supply of College Workers to High School Workers

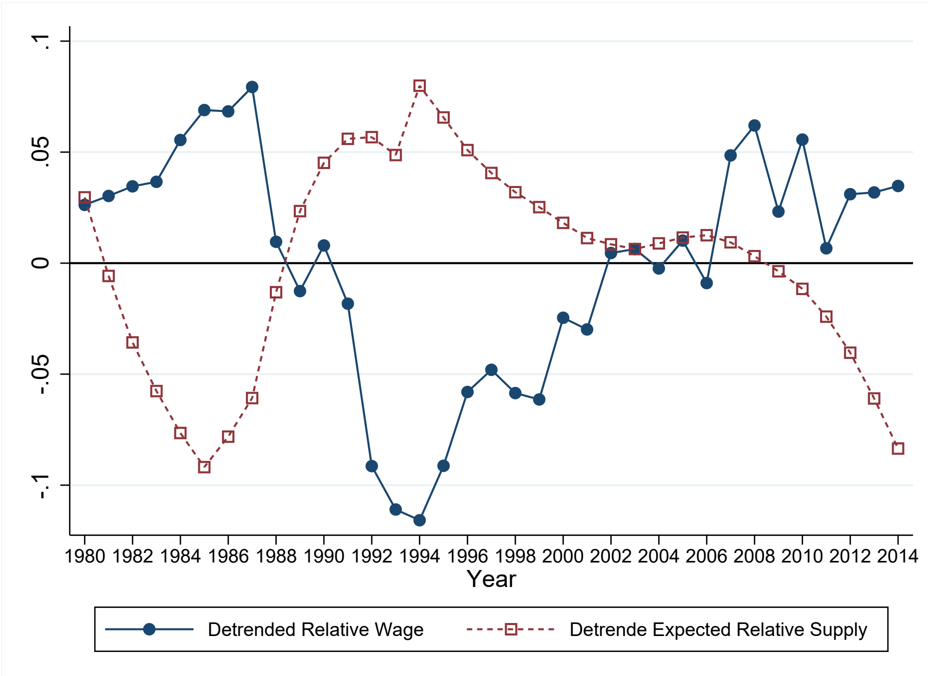


Figure 10: The Relationship between the Detrended Relative Labor Supply and the Residuals from IV Estimation

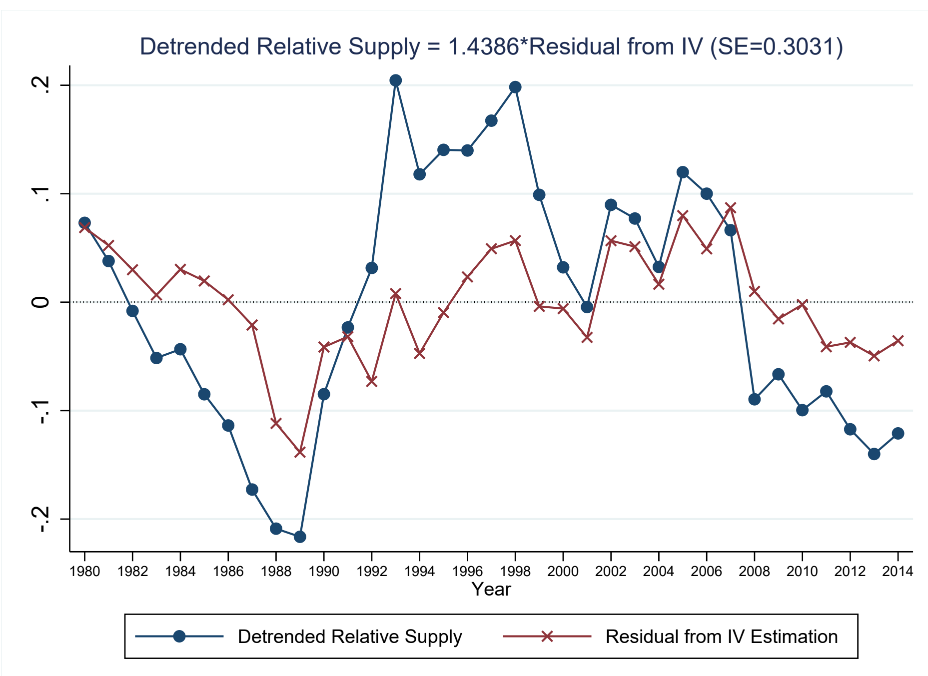
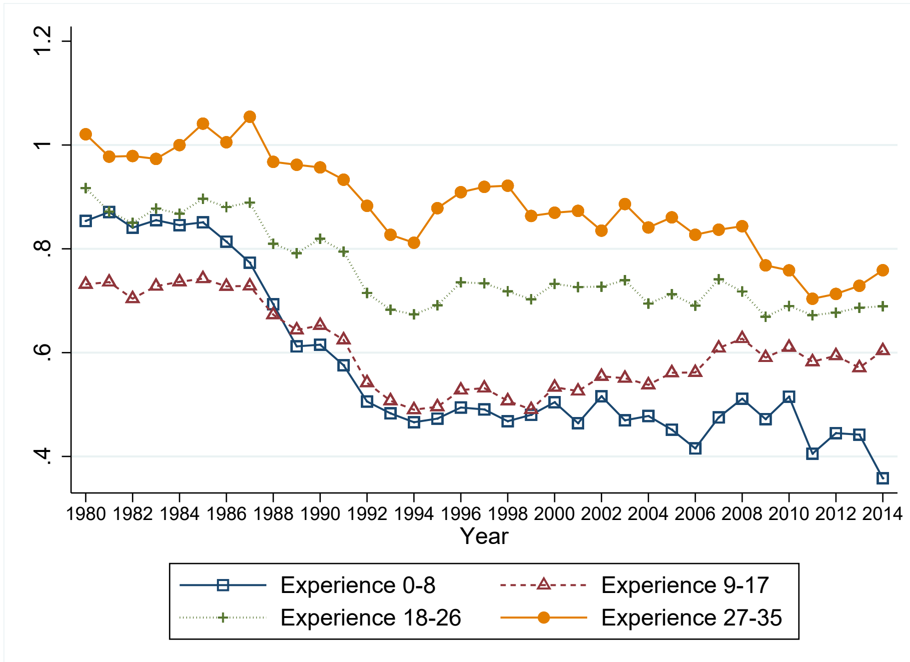
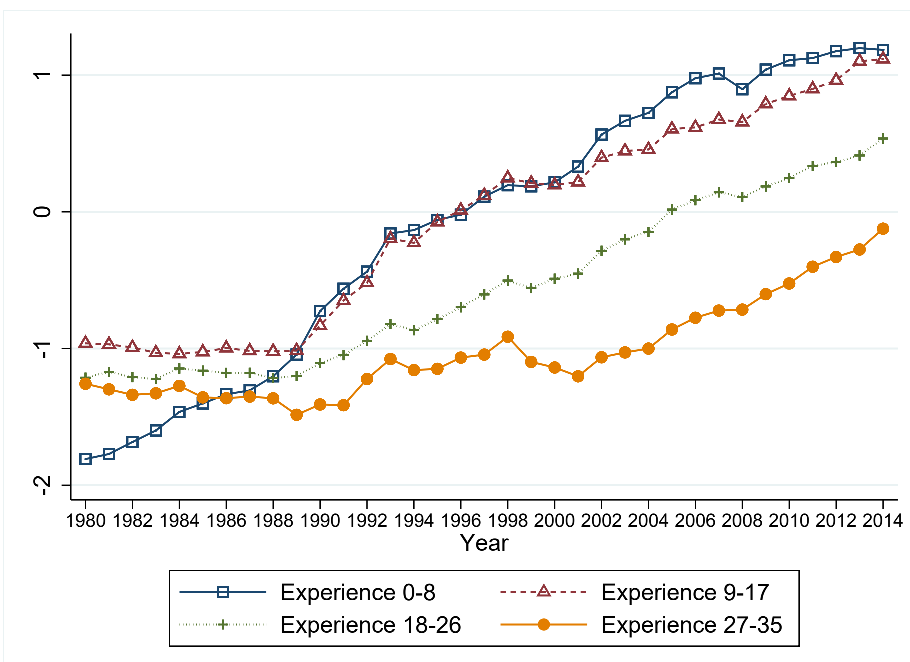


Figure 11: Relative Wage and Supply of College Workers to High School Workers by Experience Group

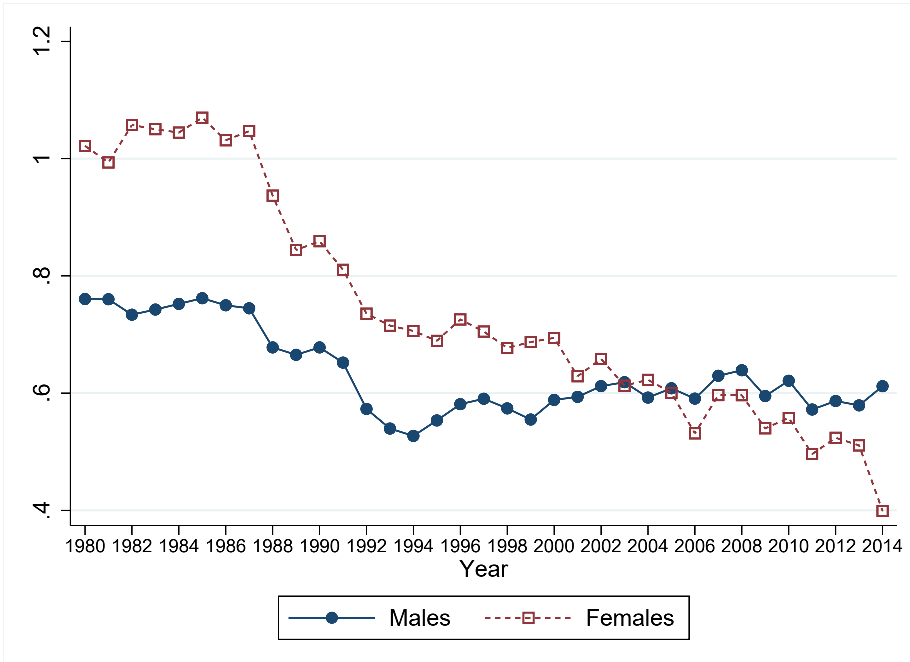


(a) Log College/High School Wage Gap by Experience Group

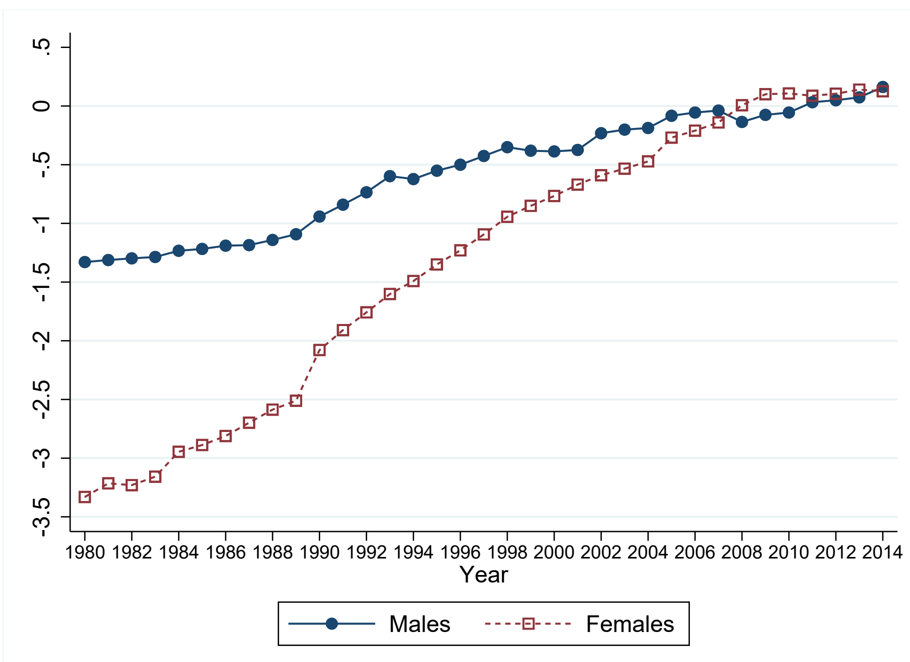


(b) Log College/High School Labor Supply Difference by Experience Group

Figure 12: Relative Wage and Supply of College Workers to High School Workers by Gender

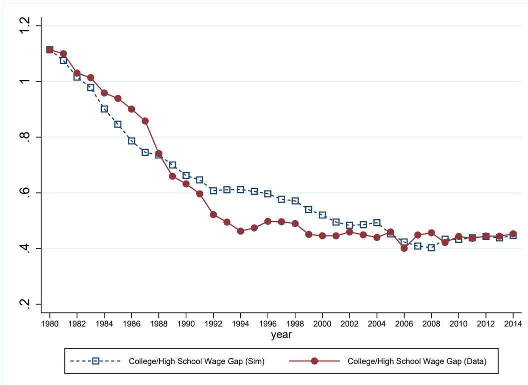


(a) Log College/High School Wage Gap by Gender

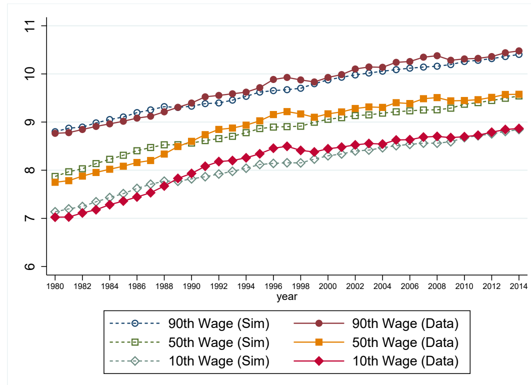


(b) Log College/High School Labor Supply Difference by Gender

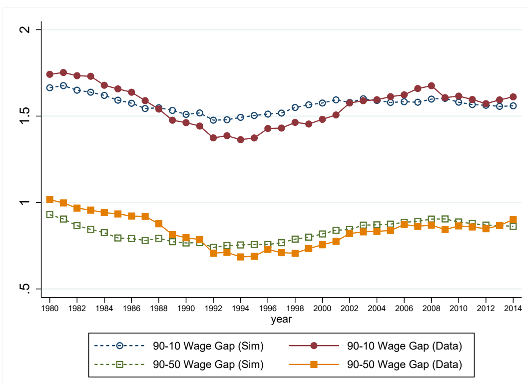
Figure 13: Model Fit: Simulation and Data Moments



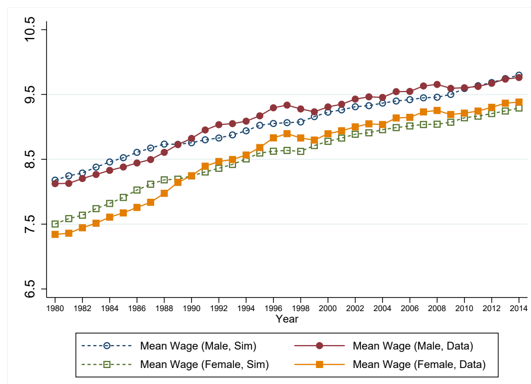
(a) Log College/High School Wage Gap



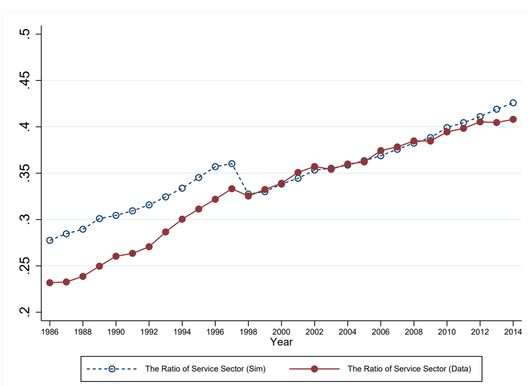
(b) Changes in Percentile Wages



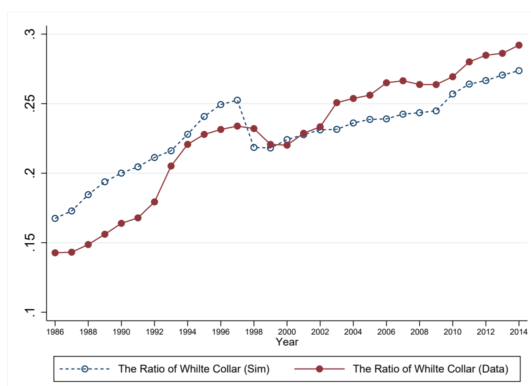
(c) Changes in Percentile Wages Gaps



(d) Changes in Mean Wage by Gender

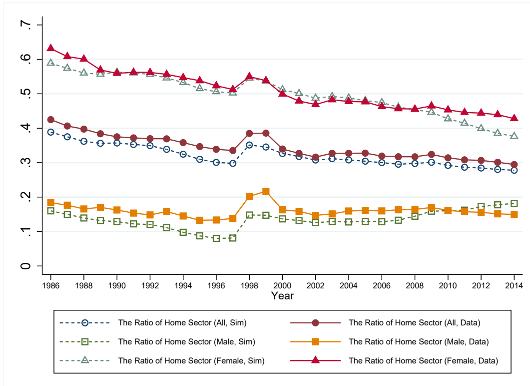


(e) The Ratio of Service Sector Workers to Population

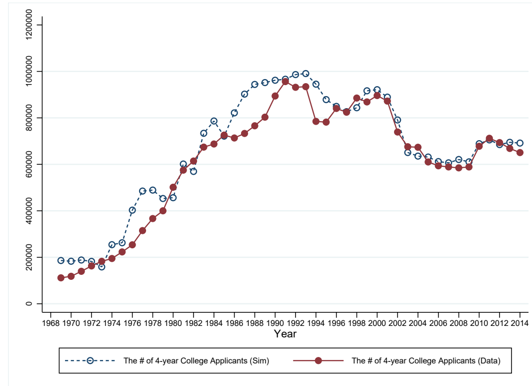


(f) The Ratio of White Collar Workers to Population

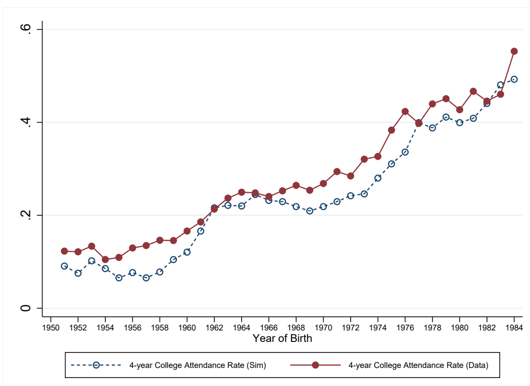
Figure 13: Model Fit: Simulation and Data Moments (Continued)



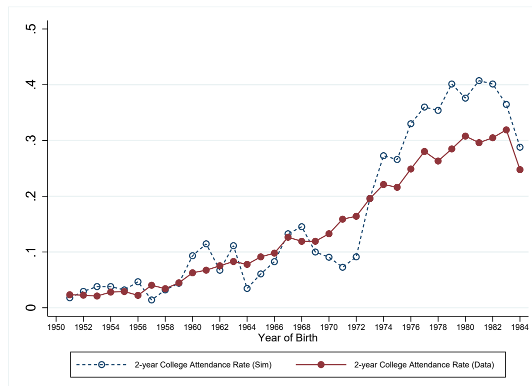
(g) The Proportion of Home sector



(h) The Number of 4-year College Applicants

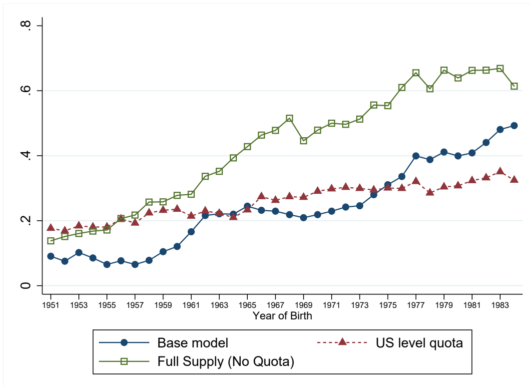


(i) 4-year College Attendance Rate

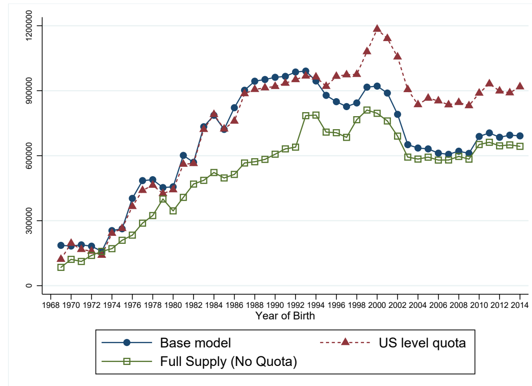


(j) 2-year College Attendance Rate

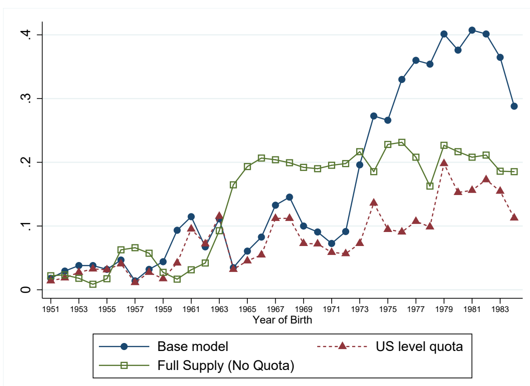
Figure 14: Counterfactual Experiment I: Manipulation of College Enrollment Quota



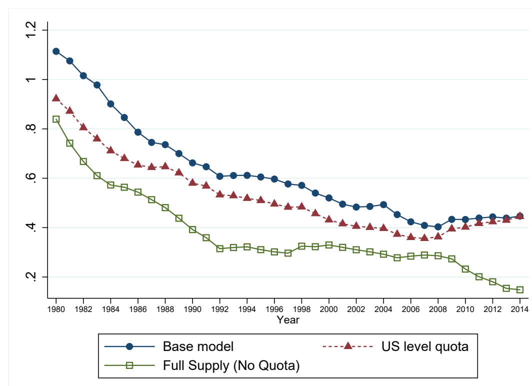
(a) 4-year College Enrollment Rate



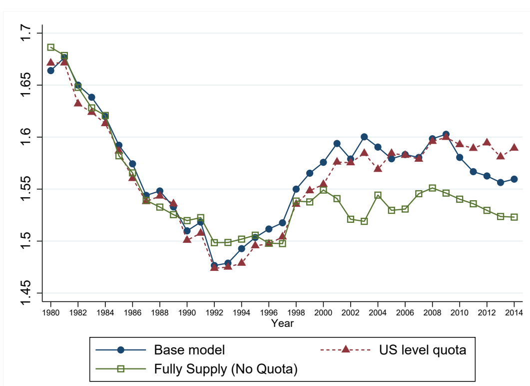
(b) The Number of 4-year College Applicants



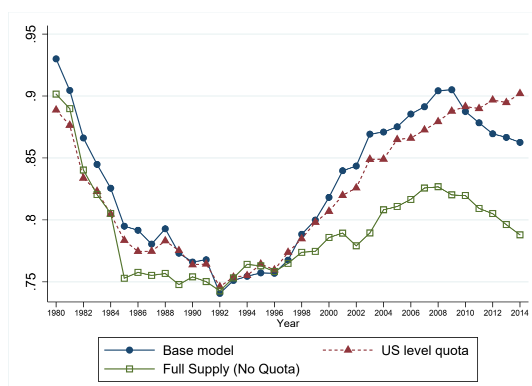
(c) 2-year College Enrollment Rate



(d) Log College/High School Wage Gap

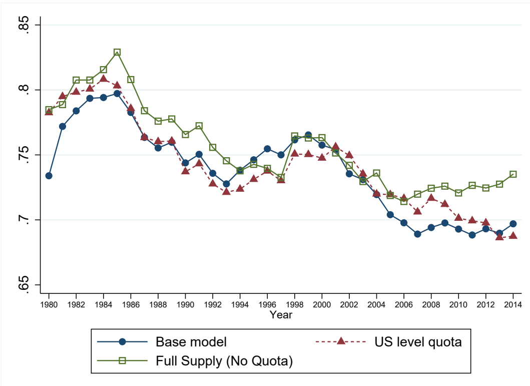


(e) Changes in 90-10 Percentile Wage Gap

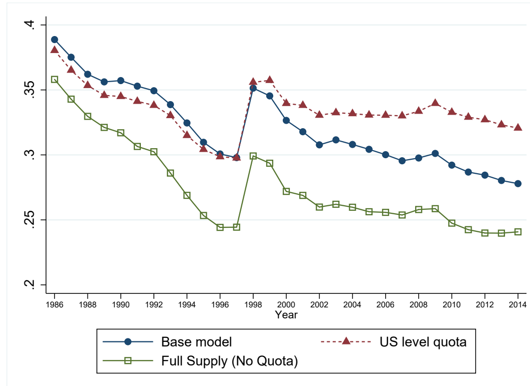


(f) Changes in 90-50 Percentile Wage Gap

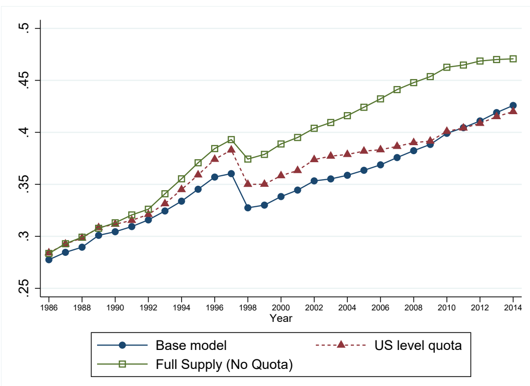
Figure 14: Counterfactual Experiment I: Manipulation of College Enrollment Quota (Continued)



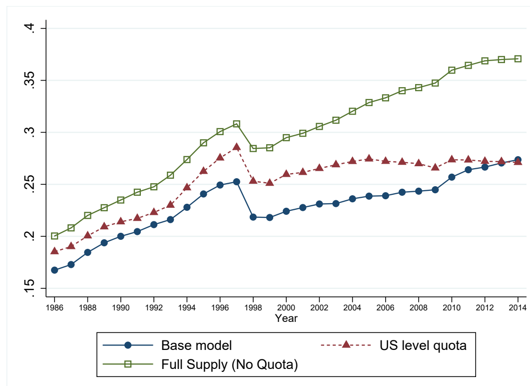
(g) Changes in 50-10 Percentile Wage Gap



(h) The Proportion of Home Sector

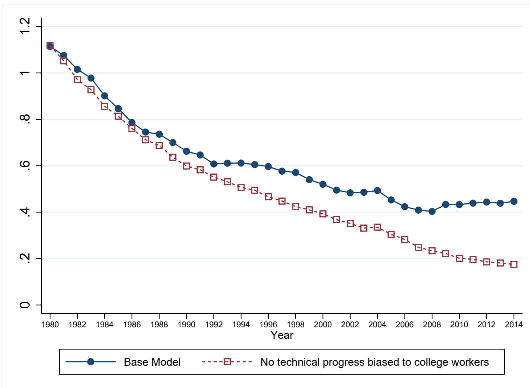


(i) The Proportion of Service Sector

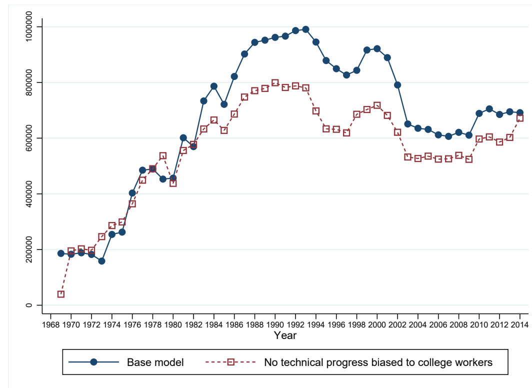


(j) The Proportion of White Collar Occupation

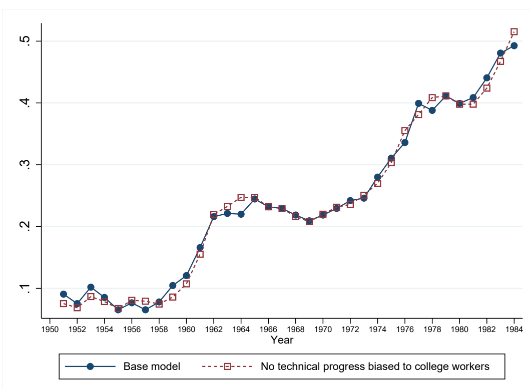
Figure 15: Counterfactual Experiment II: No Technical Progress Biased to College-Educated Workers



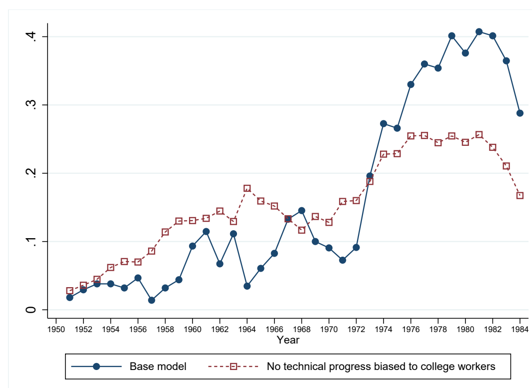
(a) Changes in College Premium



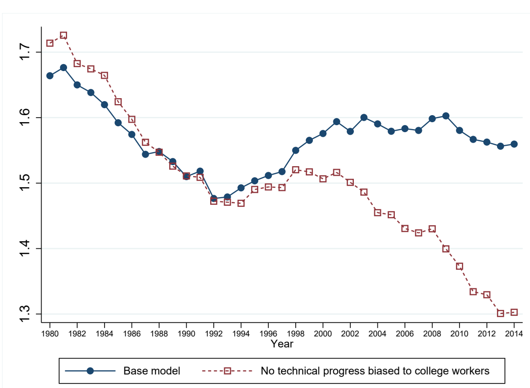
(b) The Number of 4-year College Applicants



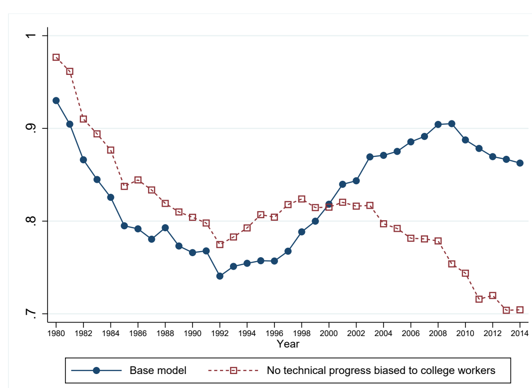
(c) 4-year College Attendance Rate



(d) 2-year College Attendance Rate

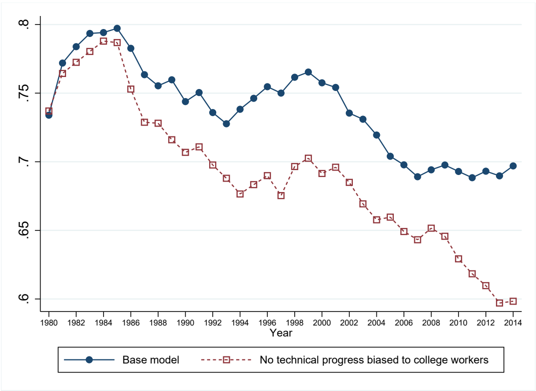


(e) Changes in 90-10 Wage Gap

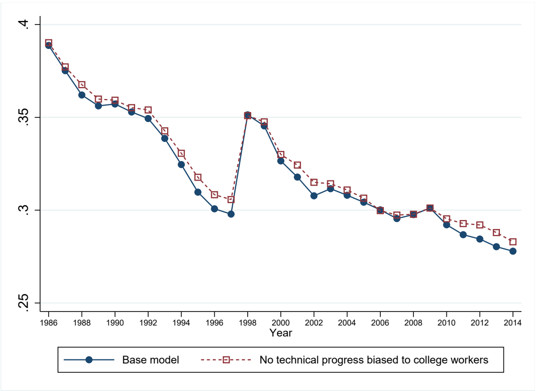


(f) Changes in 90-50 Wage Gap

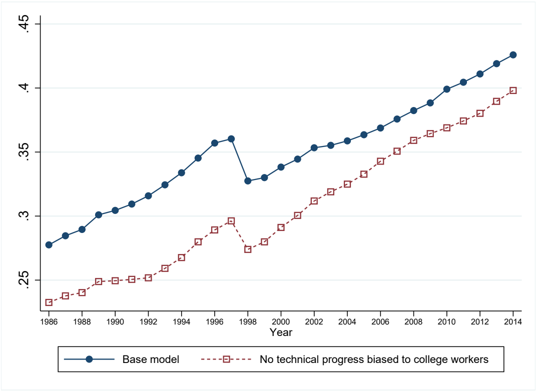
Figure 15: Counterfactual Experiment II: No Technical Progress Biased to College-Educated Workers (Continued)



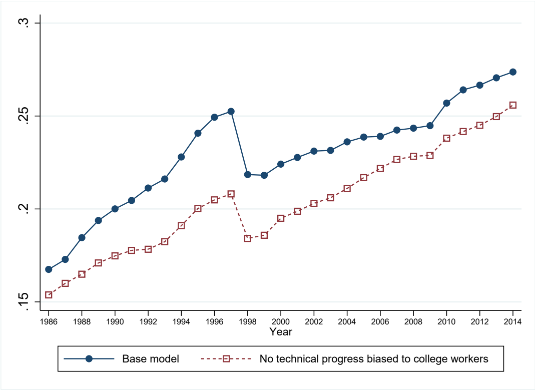
(g) Changes in 50-10 Wage Gap



(h) The Proportion of Home Sector



(i) The Proportion of Service Sector



(j) The Proportion of White Collar Occupation

Table 1: The Example of College Enrollment Quota Table (from Page 1 in college quota table in 1958 Education Statistics)

College name	Major	Enrollment quota
Seoul National University		
College of Engineering		
	Textile Engineering	40
	Chemical Engineering	40
	Civil Engineering	45
	Architectural Engineering	40
	Electronic Engineering	50
	Telecommunication	25
	Naval Architecture and Aerospace Engineering	25
	Mining Engineering	40
	Metallurgical Engineering	30
College of Agriculture		
	Agriculture	40
	Silk Yarn	30
	Forestry	20
	Agricultural Engineering	40
	Animal Husbandry	35
	Agricultural Chemistry	35
	Agricultural Economics	40

Table 2: The Effect of Relative Supply of College Workers to High School Workers on the Relative Wage: the OLS Estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Relative	-0.140***	-0.299***	-0.223***	-0.196***	-0.419***	-0.301***	-0.321***	-0.229***
labor supply	(0.012)	(0.060)	(0.046)	(0.060)	(0.051)	(0.057)	(0.053)	(0.043)
Year		0.010**	-0.005	-0.005	0.015***	0.018***	0.003	0.002
		(0.004)	(0.004)	(0.006)	(0.003)	(0.005)	(0.004)	(0.005)
Year×post-1991			0.014***				0.009***	0.013***
			(0.002)				(0.003)	(0.002)
$\text{Year}^2/100$				0.026***				
				(0.008)				
Unionization rate					-0.025***		-0.015***	
					(0.005)		(0.005)	
Minimum wage						-0.005**		-0.004**
						(0.002)		(0.002)
Observations	35	35	35	35	35	35	35	35
R-squared	0.817	0.851	0.925	0.892	0.919	0.871	0.941	0.936

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: The Effect of Expected Relative Supply of College Workers to High School Workers on the Actual Relative Supply: the First Stage Estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Relative	0.936***	1.577***	1.899***	1.333***	2.023***	2.091***	1.994***	2.850***
labor supply	(0.024)	(0.347)	(0.459)	(0.474)	(0.203)	(0.355)	(0.264)	(0.459)
Year		-0.044*	-0.073*	-0.021	-0.081***	-0.054**	-0.079***	-0.114***
		(0.024)	(0.036)	(0.038)	(0.014)	(0.021)	(0.021)	(0.032)
Year×post-1991			0.011				-0.001	0.021**
			(0.010)				(0.006)	(0.009)
$\text{Year}^2/100$				-0.018				
				(0.024)				
Unionization rate					-0.064***		-0.065***	
					(0.008)		(0.008)	
Minimum wage						-0.017***		-0.021***
						(0.006)		(0.006)
Observations	35	35	35	35	35	35	35	35
R-squared	0.979	0.981	0.982	0.982	0.994	0.985	0.994	0.988

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: The Effect of Relative Supply of College Workers to High School Workers on the Relative Wage: the IV Estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Relative	-0.139***	-0.581***	-0.360***	-0.550***	-0.463***	-0.482***	-0.347***	-0.266***
labor supply	(0.012)	(0.125)	(0.087)	(0.195)	(0.059)	(0.090)	(0.066)	(0.058)
Year		0.028***	0.006	0.025	0.018***	0.029***	0.005	0.005
		(0.008)	(0.007)	(0.017)	(0.003)	(0.007)	(0.005)	(0.006)
Year×post-1991			0.011***				0.008***	0.012***
			(0.003)				(0.003)	(0.002)
$Year^2/100$				0.004				
				(0.015)				
Unionization rate					-0.027***		-0.017***	
					(0.005)		(0.006)	
Minimum wage						-0.005*		-0.004**
						(0.003)		(0.002)
Observations	35	35	35	35	35	35	35	35
R-squared	0.817	0.749	0.903	0.771	0.918	0.829	0.941	0.935

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: The Effect of Relative Supply of College Workers to High School Workers on the Relative Wage by Potential Experience: the OLS Estimation

	(1)	(2)	(3)
Own group supply	-0.090***	-0.090***	-0.109***
minus aggregate supply	(0.014)	(0.015)	(0.031)
Aggregate relative supply	-0.325***	-0.331***	-0.329***
	(0.047)	(0.048)	(0.032)
Unionization rate	-0.015***	-0.022***	-0.015***
	(0.005)	(0.004)	(0.003)
Year	0.002	0.002	
	(0.004)	(0.004)	
Year×post-1991	0.012***		
	(0.002)		
$Year^2/100$		0.024***	
		(0.005)	
Year×Exp.0-8			-0.005
			(0.004)
Year×Exp.9-17			0.001
			(0.003)
Year×Exp.18-26			0.003
			(0.003)
Year×Exp.27-35			0.008**
			(0.004)
Year×post-1991×Exp.0-8			0.020***
			(0.003)
Year×post-1991×Exp.9-17			0.019***
			(0.003)
Year×post-1991×Exp.18-26			0.013***
			(0.003)
Year×post-1991×Exp.27-35			-0.0003
			(0.003)
Observations	140	140	140
R-squared	0.925	0.922	0.967

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: The Effects of Expected Aggregate and Within Experience Group Relative Supplies of College Workers to High School Workers on the Actual Aggregate and Within Experience Group Relative Supply: the First Stage Estimation

	(1)	(2)	(3)
(a) Own group relative supply			
Expected own group	0.740***	0.742***	0.399***
relative supply	(0.038)	(0.038)	(0.049)
Expected aggregate	0.352	0.288	-0.035
relative supply	(0.359)	(0.385)	(0.193)
R-squared	0.918	0.918	0.979
(b) Aggregate relative supply			
Expected own group	0.002	-0.001	0.014
relative supply	(0.014)	(0.014)	(0.036)
Expected aggregate	1.978***	2.093***	1.992***
relative supply	(0.133)	(0.141)	(0.141)
R-squared	0.994	0.994	0.994
Year	Y	Y	Y
Unionization rate	Y	Y	Y
Year×post-1991	Y	N	Y
$Year^2/100$	N	Y	N
Year×Experience Dummies	N	N	Y
Year×post-1991×Experience Dummies	N	N	Y

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: The Effect of Relative Supply of College Workers to High School Workers on the Relative Wage by Potential Experience: the IV Estimation

	(1)	(2)	(3)
Own group supply	-0.064***	-0.064***	-0.206***
minus aggregate supply	(0.017)	(0.017)	(0.054)
Aggregate relative supply	-0.351***	-0.349***	-0.387***
	(0.060)	(0.062)	(0.043)
Unionization rate	-0.017***	-0.023***	-0.016***
	(0.005)	(0.004)	(0.004)
Year	0.005	0.004	
	(0.005)	(0.005)	
Year×post-1991	0.011***		
	(0.003)		
$\text{Year}^2/100$		0.021***	
		(0.006)	
Year×Exp.0-8			0.006
			(0.006)
Year×Exp.9-17			0.004
			(0.004)
Year×Exp.18-26			0.002
			(0.005)
Year×Exp.27-35			0.004
			(0.005)
Year×post-1991×Exp.0-8			0.015***
			(0.004)
Year×post-1991×Exp.9-17			0.022***
			(0.003)
Year×post-1991×Exp.18-26			0.018***
			(0.005)
Year×post-1991×Exp.27-35			0.005
			(0.005)
Observations	140	140	140
R-squared	0.923	0.920	0.964

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: The Effect of Relative Supply of College Workers to High School Workers on the Relative Wage by Gender: the OLS Estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Own gender	-0.184***	-0.185***	0.028	-0.0005	0.437	0.365	0.016	-0.008
relative supply	(0.012)	(0.012)	(0.052)	(0.067)	(0.375)	(0.413)	(0.057)	(0.067)
Aggregate	-0.384***	-0.411***	-0.374***	-0.388***	-0.196**	-0.218**	-0.478***	-0.491***
relative supply	(0.052)	(0.054)	(0.043)	(0.046)	(0.087)	(0.098)	(0.062)	(0.063)
Unionization	-0.024***	-0.026***	-0.022***	-0.026***	-0.014**	-0.021***	-0.034***	-0.034***
rate	(0.005)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.006)	(0.005)
Year	0.013***	0.016***	-0.002	0.003	0.003	0.004	0.008	0.011
	(0.004)	(0.005)	(0.006)	(0.008)	(0.005)	(0.005)	(0.007)	(0.008)
Year×post-1991	0.001		0.004		0.013***		-0.001	
	(0.003)		(0.004)		(0.003)		(0.004)	
Year^2		-0.003		0.002		0.024***		-0.006
		(0.006)		(0.010)		(0.008)		(0.010)
Year×Males			0.012**	0.009				
			(0.006)	(0.008)				
Year×Males			0.004					
×post-1991			(0.004)					
Year^2×Males				0.013				
				(0.011)				
Observations	70	70	70	70	35	35	35	35
R-squared	0.950	0.950	0.966	0.965	0.881	0.859	0.979	0.979

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Parameter Estimates

(a) Factor Intensity			
Manufacturing		Service	
α_{10}^M	0.6865	α_{10}^R	0.7285
	(0.0071)		(0.0554)
α_{11}^M	0.00299	α_{11}^R	0.00299
	(0.00015)		(0.000022)
α_{12}^M	-0.00123	α_{12}^R	0.00204
	(0.000012)		(0.00015)
α_{20}^M	0.1366	α_{20}^R	0.293
	(0.0038)		(0.0050)
α_{21}^M	0.00654	α_{21}^R	0.00201
	(0.00028)		(0.000083)
α_{22}^M	0.00810	α_{22}^R	0.0117
	(0.00013)		(0.00042)
$(1-\alpha_{10}^M)\alpha_{20}^M$	0.0430	$(1-\alpha_{10}^R)\alpha_{20}^R$	0.0797
$(1-\alpha_{11}^M)\alpha_{21}^M$	0.00652	$(1-\alpha_{11}^R)\alpha_{21}^R$	0.00200
$(1-\alpha_{12}^M)\alpha_{22}^M$	0.00811	$(1-\alpha_{12}^R)\alpha_{22}^R$	0.0117
Education			
α_{30}	0.5998		
	(0.0148)		
α_{31}	-0.000068		
	(0.000099)		
α_{32}	-0.00383		
	(0.000104)		
Age group			
α_{40}	0.513		
	(0.0330)		
α_{41}	-0.000651		
	(0.000016)		
α_{42}	-0.000373		
	(0.000030)		
(b) Elasticity of Substitution			
σ	0.6583	$\frac{1}{1-\sigma}$	2.927
(Blue-Composite)	(0.0121)		
ν	0.5758	$\frac{1}{1-\nu}$	2.357
(White-Capital)	(0.0320)		
ρ_c	0.5172	$\frac{1}{1-\rho_c}$	2.071
(High school-college)	(0.0316)		
ρ_a	0.9150	$\frac{1}{1-\rho_a}$	11.76
(Younger-older)	(0.0500)		

Standard errors in parentheses

(Continued)

(c) Home production	
φ_0	1.031
	(0.0344)
φ_1	8.903
	(0.0780)
φ_2	-0.209
	(0.00273)
φ_3	0.0005
	(0.0000075)
φ_4	0.0745
	(0.00242)
φ_5	8.393
	(0.1786)
φ_6	0.0432
	(0.00071)
φ_7	0.4612
	(0.0147)
φ_8	-293.0
	(10.147)
(d) Shocks	
$\epsilon^{M,W}$	0.167
	(0.0110)
$\epsilon^{M,B}$	0.266
	(0.0047)
$\epsilon^{S,W}$	0.353
	(0.0073)
$\epsilon^{S,B}$	0.169
	(0.0075)
ϵ_h	11000.1
	(65.33)
(e) Human capital	
$\beta_0^{M,W}$	2.620
	(1.021)
$\beta_0^{M,B}$	4.153
	(0.1634)
$\beta_0^{S,W}$	3.012
	(0.0235)
$\beta_0^{S,B}$	4.218
	(0.1475)
$\beta_1^{M,W}$	0.531
	(0.0236)
$\beta_1^{M,B}$	0.401
	(0.0028)
$\beta_1^{S,W}$	0.433
	(0.0063)
$\beta_1^{S,B}$	0.560
	(0.0113)

Standard errors in parentheses

(Continued)

(e) Human capital (continued)			
β_3	0.0481		
	(0.00094)		
β_4	-0.000692		
	(0.000063)		
β_5	0.0289		
	(0.00068)		
β_6	0.00000347		
	(0.00000191)		
$\beta_7^{M,W}$	0.185		
	(0.0108)		
$\beta_7^{M,B}$	0.131		
	(0.0017)		
$\beta_7^{S,W}$	0.169		
	(0.0053)		
$\beta_7^{S,B}$	0.123		
	(0.0074)		
(f) Education demand			
4-year college		2-year college	
θ_0^0	-328387.5	θ_0^1	-101910.0
	(6985.9)		(9366.8)
θ_1^0	-328921.4	θ_1^1	-213925.4
	(9445.9)		(1703.1)
θ_2^0	-915913.2	θ_2^1	-169000.2
	(14902.81)		(24965.0)
θ_3^0	0.0372	θ_3^1	0.0091
	(0.0013)		(0.00016)
θ_4^0	0.0244	θ_4^1	-0.0099
	(0.0003)		(0.000063)
σ_{E_1}	132300.8	σ_{E_2}	129800.9
	(1683.1)		(1975.3)
(g) College admission			
4-year college		2-year college	
ϕ_1^1	-0.108	ϕ_1^2	-0.100
	(0.0243)		(0.00036)
ϕ_2^1	0.996	ϕ_2^2	1.001
	(0.0049)		(0.0052)
ϕ_3^1	1.492	ϕ_3^2	1.500
	(0.0464)		(0.0675)
σ_{s_7}	2.782	σ_{s_6}	8.50
	(0.1686)		(0.2944)

Standard errors in parentheses

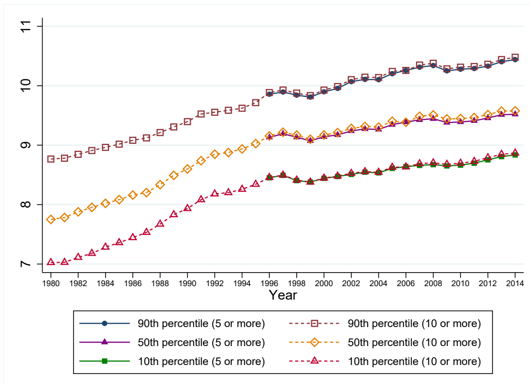
(Continued)

(h) Sector-Occupation Preference			
Males		Females	
π_1^1	-9700.2	π_1^2	-7690.0
	(521.7)		(57.2)
π_2^1	8359.4	π_2^2	1740.0
	(380.1)		(36.8)
π_3^1	-7010.2	π_3^2	-2110.1
	(179.7)		(32.9)
π_4^1	4080.4	π_4^2	370.4
	(31.8)		(4.83)
(i) Moving Cost			
κ_1	964817.2		
	(37799.1)		
κ_2	-8499.5		
	(195.9)		
κ_3	257002.3		
	(1882.5)		
κ_4	8943.3		
	(335.5)		

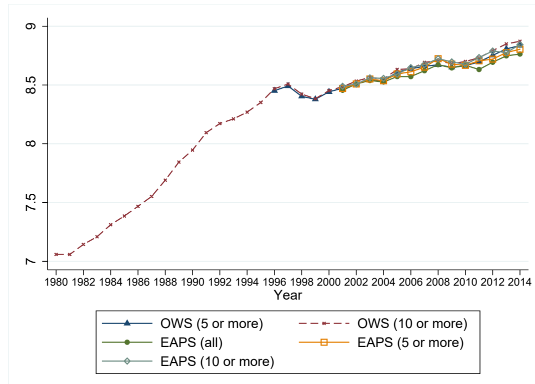
Standard errors in parentheses

Appendix A Investigation of the Possibility of Sample Selection in OWS

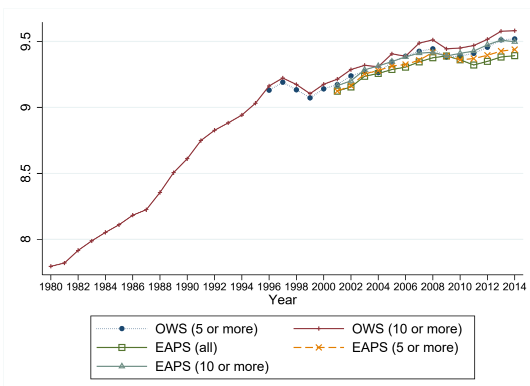
Figure A1: Log Percentile Wage by Firm Size and Data



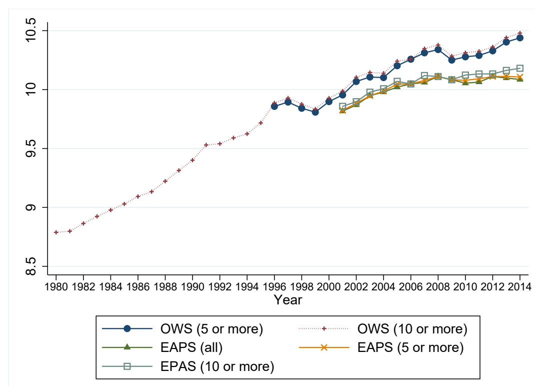
(a) Percentile Wages by Firm Size



(b) 10th Percentile Wage by Firm Size and Data



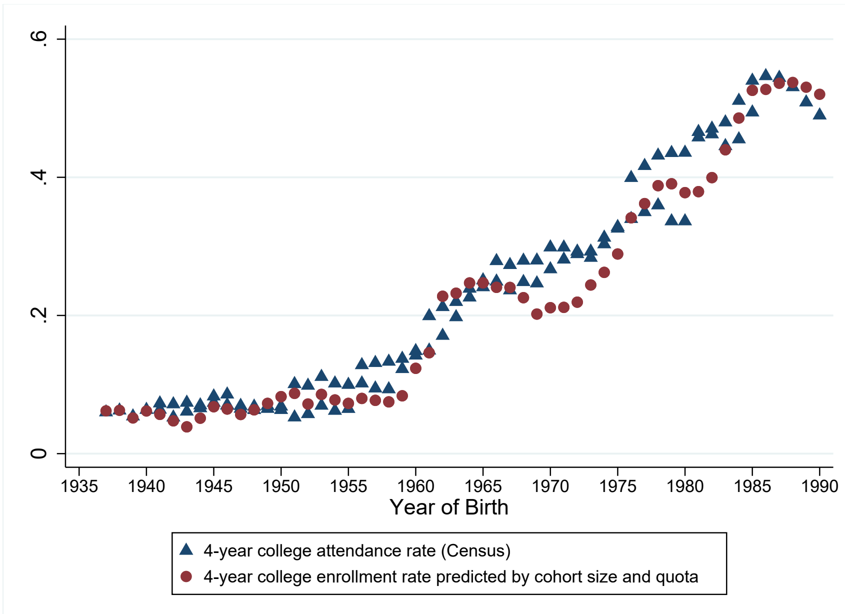
(c) 50th Percentile Wage by Firm Size and Data



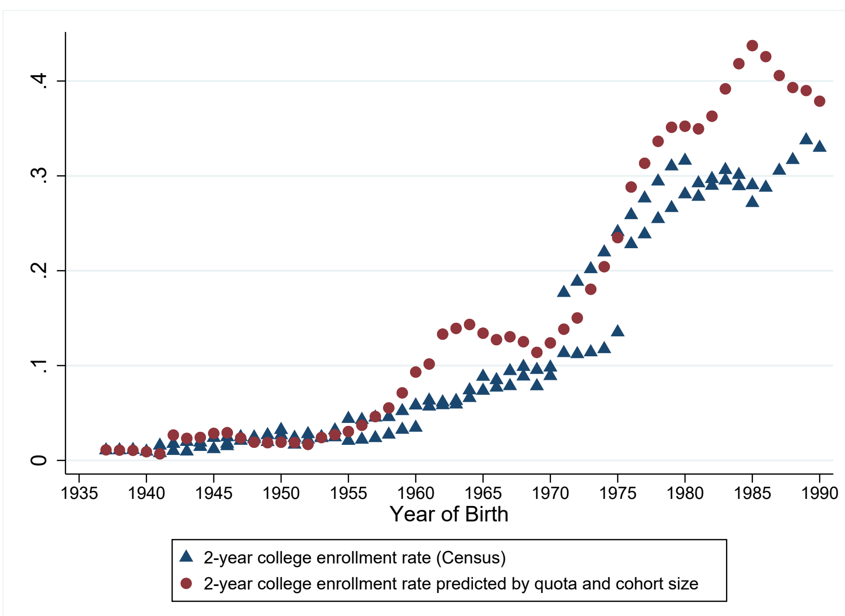
(d) 90th Percentile Wage by Firm Size and Data

Appendix B Actual and Predicted College Attendance Rates for Longer Time Horizon (Census 1966-2010)

Figure A2: Actual and Predicted College Attendance Rates from the census 1966-2010



(a) Actual and Predicted 4-year College Attendance Rates



(b) Actual and Predicted 2-year College Attendance Rates

Appendix C The Relationship between Real GDP Growth Rate and College Enrollment Quota

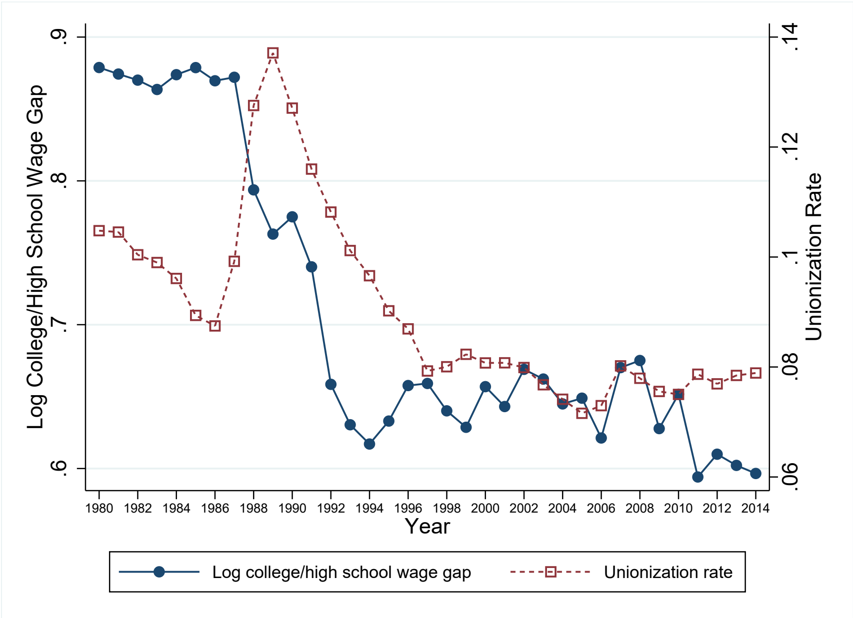
Table A1: The Relationship between Real GDP Growth Rate and College Enrollment Quota

	(1)	(2)	(3)	(4)	N
Log Real GDP	0.414***	-0.054	-0.048	-0.033	51
Growth Rate in t	(0.102)	(0.066)	(0.062)	(0.057)	
Log Real GDP	0.390***	0.036	0.032	0.011	48
Growth Rate in t+4	(0.114)	(0.075)	(0.071)	(0.067)	
Log Real GDP	0.289**	0.022	0.009	-0.037	45
Growth Rate in t+7	(0.113)	(0.077)	(0.073)	(0.070)	
Time Trend	Linear	Quadratic	Cubic	Quartic	

1. Dependent variable is log college enrollment quota in t.
2. Standard errors in parentheses
3. *** p<0.01, ** p<0.05, * p<0.1

Appendix D College/High School Wage Gap and Labor Market Institutions

Figure A3: College/High School Wage Gap and Labor Market Institutions

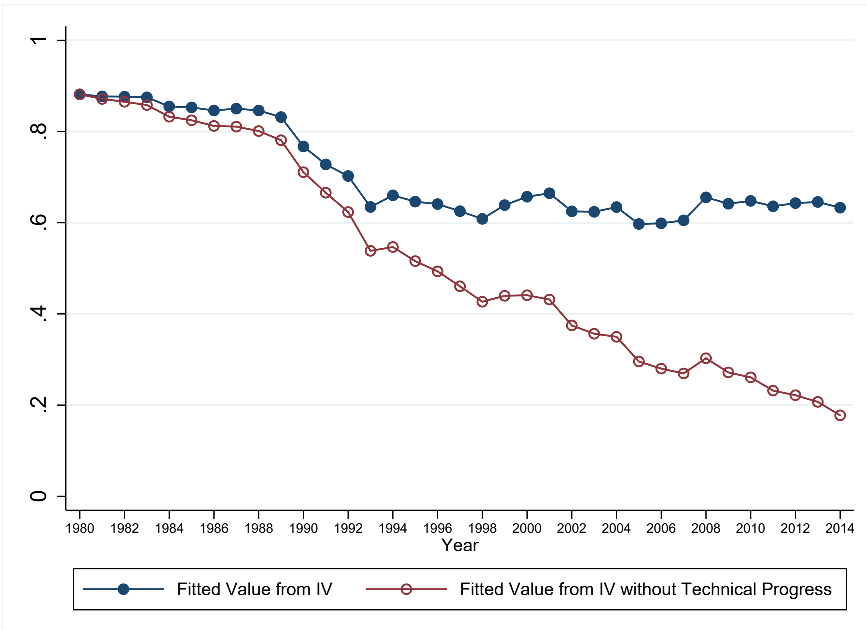


(a) Log College/High School Wage Gap and Unionization Rate

(b) Log College/High School Wage Gap and Minimum Wage

Appendix E Counterfactual from IV Estimation: No Technical Progress Biased to College Workers

Figure A4: The Predicted College Premiums When There Was and There Was Not Technical Progress Biased to College Workers from IV Estimations



Appendix F Mandatory Military Service in South Korea

Table A2: Terms of Mandatory Military Service for Males

Year	Terms of military service
1953-1959	36 months for the army, the navy and the air force
1959-1962	33 months for the army, 36 months for the navy and the air force
1962-1968	30 months for the army, 36 months for the navy and the air force
1968-1977	36 months for the army, 39 months for the navy and the air force
1977-1979	33 months for the army, 39 months for the navy and the air force
1979-1984	33 months for the army, 35 months for the navy and the air force
1984-1993	30 months for the army, 32 months for the navy, and 35 months for the air force
1993-1994	26 months for the army, 30 months for the navy and the air force
1994-2003	26 months for the army, 28 months for the navy, and 30 months for the air force
2003-2004	24 months for the army, 26 months for the navy, and 28 months for the air force
2004-2011	24 months for the army, 26 months for the navy, and 27 months for the air force
2011-	21 months for the army, 23 months for the navy, and 24 months for the air force

Appendix G Calculation Method of the Predicted Ratio of College Workers to High School Workers by Experience

- The predicted number of 4-year college workers in experience group m in year t (Q_{1mt}): the sum of 4-year college quotas for cohorts in experience group m whose age is between 25(24) and 66 for the years before 1994 (after 1993).

- The predicted number of 2-year college workers in experience group m (Q_{2mt}): the sum of 2-year college quotas for cohorts in experience group m whose age is between 24(23) and 66 for the years before 1994 (after 1993).

- The predicted number of high school or lower workers in experience group m in year t (Q_{3mt}): the number of people in experience group m whose age is between 22(21) and 66 - the sum of the predicted 4-year and 2-year college workers in experience group m for the years before 1994 (after 1993).

The predicted ratio of college equivalent workers in experience group m is calculated as the ratio of the sum of the predicted 4-year college workers and the half of the predicted 2-year college workers in experience group m to the sum of the predicted high school workers and the half of the predicted 2-year college workers in experience group m ($\frac{Q_{1mt} + \frac{1}{2}Q_{2mt}}{Q_{3mt} + \frac{1}{2}Q_{2mt}}$) for m=1,2,3,4,5,6.

Appendix H Estimation Procedure

This study follows the estimation procedure in Lee (2005) and Lee and Wolpin (2006). The economy starts in 1961. The real-valued aggregate output and physical capital stock by sector from 1961 to 2014 are taken from data. It is assumed that physical capital stock is fixed at the level in data (exogenous capital). The initial conditions of individuals who start to make a decision at age 19 include gender, education level, parental education level and father's occupation and they are extracted from the census micro data. For individuals who are older than 19 in 1961, the choice in 1960 and work-experience by sector-occupation are additionally extracted from the census. Given this information, the parameters are estimated from the following procedure:

1. Start with an initial guess on parameters.
2. Solve the Bellman equation given the parameters.
3. Draw the idiosyncratic individual shocks
4. For each year, start with an initial guess on skill prices in the first iteration. Otherwise, start with skill prices achieved in step 6. Simulate the individuals choices in the sample.
5. Calculate the aggregate human capital for each sector-occupation-education-age group.
6. Calculate the aggregate productivity shock by equating the output from simulation and that from data for each sector. Get the marginal value product at the aggregate human capital calculated in step 4 for each sector-occupation-education-age group.
7. Using the calculated marginal value products as initial skill prices, repeat steps 3-6 until the skill prices and the aggregate productivity shocks converge.
8. Using the converged skill prices and aggregate productivity shocks for all years, estimate the equations of the total factor productivity evolution (equation (12)) and the equations of skill price evolution (equation (25)).
9. Repeat 1-8 using the estimated parameters in step 8 until the parameters in the equations (12) and (25) converge.
10. Compute the loss function that is the weighted sum of distances between simulated moments and data moments.
11. Repeat 1-10 until the loss function is minimized.