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Stable Wage Distribution in Japan, 1982-2002: A Counter Example for SBTC?

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Abstract

Wage distribution has been nearly stable in Japan for the last two decades, contrary to findings in the US, Canada, and the UK. The change in wage distribution during this period was almost completely caused by a distributional change in worker attributes. This implies that skill prices were very stable between 1982 and 2002. Both demand and supply for skilled workers have increased because of skill-biased technological change (SBTC), a rise in the number of college-educated workers induced by educational policy changes, and the aging of the population. In the balance of shifts in demand and supply, the skill price has been stable. Industries that experienced rapid computerization also experienced workers' skill upgrading. We find evidence consistent with SBTC.

JEL Classification: J23; J31

Keywords: Wage Distribution; Return to Education; Skill Prices; Skill-Biased Technological Change; Japan

1 Introduction

The Liberal Democratic Party (LDP), the ruling political party of Japan, faced a major defeat in the lower house election of July 2007. Political analysts claim that concern about increased wage inequality led voters to go against the LDP, which advocates market reform by abolishing government regulations. The NHK TV program "Working Poor" reported on the lives of poor families and attracted public attention (NHK (2007) for a book summary). Media repeatedly report on the lives of the poor, and *Kakusa* (inequality) and *Karyū* (lower class) have become buzzwords in Japanese society.

Contrary to prevalent national concern about wage inequality, rigorous empirical studies continue to find a surprisingly stable wage structure in Japan.[1] These studies are based on the Basic Survey on Wage Structure, which collects individual workers' information from payroll records via a random sampling of establishments. Critics have pointed out that wage inequality does not show up in these studies because inequality has increased at the margin of non-standard workers (part-time workers, contingent workers, and workers other than full-time, permanent workers), who comprised 1/3 of the labor force as of 2007, according to the Labor Force Survey.[2]

[1] See Katz and Revenga (1989), Genda (1998), Shinozaki (2002), Ohtake (2005), Noro and Ohtake (2006) and Kambayashi et al. (2008).

[2] The Labor Force Survey survey is a monthly household survey that includes about 40 thousands implemented by Ministry of Internal Affairs and Communications. The Basic Survey on Wage Structure is an annual establishment survey by Ministry of Health, Labour and Welfare that includes part-time workers who are directly employed by establishments,

Examining Japan's wage distribution is interesting from an international perspective as well. English-speaking countries experienced increased wage dispersion throughout the 1980s and 1990s, as reported by Autor et al. (2008) for the US, Goos and Manning (2007) for the UK, and Boudarbat et al. (2003) for Canada. There remains a controversy regarding why wages have dispersed, however. One strand of scholars claims that the observed wage dispersion had been caused by skill-biased technological change (SBTC).[3] In contrast, another strand of scholars claims that changes in wage-setting institutions, such as the falling real minimum wage or the unionization rate, are critical determinants of wage dispersion.[4]

To address this controversy, it would be useful to measure the effect of technological change on the wage structure in other developed countries that presumably have experienced the same technological change. However, some continental European countries have very rigid, centralized wage-setting mechanisms, and the effect of the demand shift appears at the margin of employment rather than wage (Fitoussi (1994)). In fact, Koeniger et al. (2007) report that labor market institutions explain an important portion of the change in wage inequality. According to the index reported in Koeniger et al. (2007), Japanese labor market institutions engage less in wage-setting

but the educational backgrounds of those part-time workers are not recorded, and this prohibits researchers from including them in a sample for formal decomposition analysis.

[3]See Katz and Murphy (1992), Murphy and Welch (1992), Bound and Johnson (1992), and Autor et al. (1998) for classic works and Autor et al. (2008) and Goos and Manning (2007) for recent works.

[4]See DiNardo et al. (1996), Lee (1999), and Card and DiNardo (2002) for representative works.

than those of continental European countries. Thus, Japan is arguably an ideal testing ground for the demand-supply framework of the labor market.[5]

The purpose of this paper is to describe the change in Japan's wage distribution based on a household survey, the *Employment Status Survey*, which covers all types of workers regardless of contract form. Furthermore, we apply a simple demand-supply framework to the Japanese labor market and explain the change in the wage distribution within that framework.

An analysis of the Employment Status Survey, which includes all types of workers, reveals that Japan's wage distribution was very stable between 1982 and 2002, even after including non-regular employees in the analysis sample. Workers located at all percentiles of wage distribution evenly experienced about a 30-percent real wage gain during the period. Moreover, non-parametric decomposition analysis in DiNardo et al. (1996) reveals that the wage distribution in 2002 would be almost identical to that of 1982 if worker composition had been that of 1982. This evidence indicates that the skill price was stable between 1982 and 2002. The stable wage distribution in Japan during the period found in the previous studies was not caused by the sampling structure of the Basic Survey on Wage Structure, which does not include information on non-regular workers' educational backgrounds.

[5] The *Shunto*(Spring Offensive) is an important wage-setting institution in Japan that consists of the collective wage bargaining between labor unions and managements. The contract period is one year, which is shorter than the typical contract in the US. Synchronized bargaining prevents a sluggish wage adjustment caused by unions' failure to coordinate. Ito (1992) pointed out that, "This annual synchronized contract negotiation makes wage adjustment more flexible in Japan than in other countries."

An examination of worker characteristics reveals a rapid increase in college-educated and older workers. The increase in college-educated workers was largely caused by a change in the government's higher-education policy. As a result of this policy change and population aging, the supply of skilled workers increased exogenously. Given this exogenous supply shift, the degree of demand shift is identified, assuming the constant elasticity of substitution (CES) production technology, as in Card and Lemieux (2001) and Noro and Ohtake (2006). Analysis results reveal that the return to skill stayed constant regardless of the supply increase of college-educated workers because the demand for college-graduates relative to high-school-graduates increased during the period. It turned out, however, to be difficult to distinguish the wage-dispersing effect of technological progress and the wage-compressing effect of workers' skill upgrading because both series trend linearly.

An industry-level analysis reveals that computerization enhanced workers' skill upgrading. Industries with heavy investment in IT-related equipment experienced a more rapid increase of college-educated workers than industries with less IT investment, conditional on the initial level of college-educated workers. The fraction of PC users in the workplace in 2002 is also positively correlated with an increase of the fraction of college-educated workers in an industry. This additional evidence is consistent with SBTC.

Overall, the Japanese economy has experienced SBTC, but the exogenous increase in high-skilled workers that occurred simultaneously prevented wage-dispersion. A simple demand-supply framework well explains Japan's wage-distribution trend. The Japanese experience does not seem to be a counter example against the SBTC hypothesis.

This rest of this paper is organized as follows. Section 2 overviews the trend of Japan's wage distribution over the past two decades. Section 3 implements a Card-Lemieux estimation to identify the relative demand shift for college-educated workers, netting out the relative supply increase of such workers. Section 4 implements an industry analysis that examines the relation between computerization and skill upgrading. The last section provides a conclusion.

2 Japan's Wage Distribution

2.1 Data

The Employment Status Survey (ESS, *Shugyō Kōzō Kihon Chōsa*) for the years 1982, 1987, 1992, 1997, and 2002 is used in this study. The ESS is conducted every five years on household members aged 15 or older in approximately 440,000 households dwelling in sampled units that cover the complete population.[6] The survey collects information on household members and each member's labor force status on October 1 of each survey year.

This study utilizes microdata and extracts information on age, educational attainment, employment status, annual workdays, weekly work-hours,

[6] Foreign diplomats, foreign military personnel and their dependents, persons dwelling in camps or ships of the Japan Self-Defense Forces, and persons serving sentences in correctional institutions are excluded.

and annual income from the main job during the previous year. The file contains about one million individuals with a half-million males and a half-million females for each year that the survey was conducted. The analysis sample is restricted to those ages 22-59. Self-employed workers are included, but family workers are excluded from the sample. Family workers are dropped from the sample because it is difficult to measure their income. The sample is further restricted to observations with a valid age, educational background, and employment status. Those without job tenure conditioned on being employed are dropped.

Regarding the construction of variables, we transformed the highest educational attainment into a continuous variable. For junior high school graduates and high-school-graduates, nine and 12 years of education are assigned, respectively. Fourteen years of education is assigned for junior-college and technical-college-graduates, and 16 years for four-year-college-graduates and graduate-school graduates. The survey records annual earnings in ranges.[7] These ranges are transformed into a continuous variable by using the center value of each range. For the highest open-bracket range, the lowest value for the range is assigned for each year. Weekly work hours and annual work

[7]The annual income ranges denominated by thousand yen are: 500 or less, 500-990, 1,000-1,490, 1,500-1,990, 2,000-2,490, 2,500-2,990, 3,000-3,990, 4,000-4,990, 5,000-5,990, 6,000-6,990, 7,000-7,990, 8,000-8,990, 9,000-9,900, 10,000-14,900, and 15,000 or above for year 2002. The ranges for 1992 and 1997 are: 500 or less, 500-990, 1,000-1,490, 1,500-1,990, 2,000-2,490, 2,500-2,990, 3,000-3,990, 4,000-4,990, 5,000-6,990, 7,000-9,900, 10,000-14,900, and 15,000 or above. The ranges for 1987 and 1982 are: 500 or less, 500-990, 1,000-1,490, 1,500-1,990, 2,000-2,490, 2,500-2,990, 3,000-3,990, 4,000-4,990, 5,000-6,990, 7,000-9,900, 10,000 or above.

days also are recorded in ranges, and we transformed them into continuous variables using the same rule.[8]

Constructing the hourly wage from these brackets could result in a biased estimate of the true hourly wage, but we are concerned with the change in the hourly wage over time rather than the wage level. The ranges of the brackets for workdays are consistent over the years, as are the ranges for weekly work hours. Regarding the annual income range, change in the range of the brackets in the middle of the annual income distribution does not change the hourly wage if the annual income is uniformly distributed within the range. Although the uniform distribution assumption is likely to be violated, the bias resulting from this would be minimal.

The critical change of the brackets for our purpose is the increase in the largest range from 10 million yen or above to 15 million yen or above from 1987 to 1992. If a disproportionately large number of individuals would have earned more than 15 million, conditional on having earned more than 10 million,[9] the change of these brackets would have increased the wage dispersion in 1992 and after, even if the underlying wage rate had not changed.

To avoid this issue, we imputed those who might have earned more than 15

[8] The ranges of annual workday are: less than 50, 50-99, 100-149, 150-199, 200-249, and 250 and more for all survey years. The ranges of work-hours are: less than 15, 15-21, 22-34, 35-42, 43-48, 49-59, and 60 and more for 1987; less than 15, 15-21, 22-34, 35-42, 43-45, 46-48, 49-59, and 60 and more for 1992; less than 15, 15-21, 22-34, 35-42, 43-48, 49-59, and 60 and more for 1997; less than 15, 15-19, 20-21, 22-34, 35-42, 43-48, 49-59, and 60 and above for 2002.

[9] In fact, we do not find this in our 1992 sample, as the proportion was 0.27 for males and 0.30 for females.

million yen in 1982 and 1987 by the following procedure. First, we calculated the proportion of people who earned more than 15 million yen conditional on earning more than 10 million yen, using the 1992 sample by sexes. We call this proportion $p_{>15}$. Second, we ran separate probit regressions for both sexes, whose dependent variable is the dummy variable indicating earning more than 15 million yen, and the independent variables, which are education, experience, its square, tenure, and its square, using the individuals who earned more than 10 million yen in 1992 as the analysis sample. Third, we assigned 15 million yen in earnings for the $p_{>15}$ proportion of people who earned more than 10 million yen in 1987 based on the predicted probability to earn more than 15 million, using the probit coefficient of 1992 for both sexes. Hourly wage is calculated based on these imputed annual earnings.

All wages are deflated by the consumer price index of the Ministry of Internal Affairs and Communications. Employed workers in this study include those who worked with and without a term contract (*rinji rodosha* and *joyo rodosha*) and all other types of employment - regular employees, part-time employees, *arubaito*, temporary (dispatched) employees, short-term contract employees, and others. Aggregate variables used in section 3 are constructed from the micro-sample described above.

2.2 Trends in the Wage Distribution

Figure 1, Panel A reports that the wage differential between the 90th and 50th percentiles among males increased between 1987 and 1992, but stayed constant after that period until 2002. The difference between the 50th and 10th percentiles was stable until 1997, but increased slightly between 1997 and 2002. The trend for the upper-tail distribution contrasts with the trend for the US, whereas the 90/50 difference increased consistently throughout the 1980s, 1990s, and early-2000s (Autor et al. (2008)). The trends for female employees reported in Figure 1, Panel B indicate almost stable 90/50 wage differentials and narrowing 50/10 wage differentials.

Figure 2, Panel A reports the wage-rate growth for each percentile of the wage distribution between 1982 and 2002. The diagram is slightly upward-sloping among males, which implies that male employees in higher percentiles experienced higher wage growth than those in lower percentiles. In contrast, women located in the lower percentiles of the distribution experienced higher wage growth than women located in the higher percentiles of the wage distribution. Figure 2, Panels B to E are the same figures for the 1982-1987, 1987-1992, 1992-1997, and 1997-2002 periods. The basic findings are consistent across analysis periods. It is notable that male workers experienced negative real-wage growth between 1997 and 2002. This is a result of the severe economic recession during this period.

The upper tail of the wage distribution grew at a faster pace than the lower tail. This can be explained by either the rapid growth of skill-endowment among skilled workers or an increase of the skill price. To distinguish these two hypotheses, we apply the DiNardo et al. (1996)'s non-parametric estimation to the data. Wage distributions of 1982 and 2002 are estimated through a Naradaya-Watson non-parametric density estimator. Then we calculate the counter-factual wage distribution that would have prevailed in 2002 if the workers' skill composition had been that of 1982 and the skill price had been that of 2002. The counter-factual wage distribution is expressed as:

$$\begin{aligned} f^{2002}_{x=1982}(\ln w) &= \int f^{2002}(\ln w|x)h(x|t=1982)dx \\ &= \int \theta f^{2002}(\ln w|x)h(x|t=2002)dx, \end{aligned} \tag{1}$$

where $\theta = \frac{P(t=1982|x)}{1-P(t=1982|x)}\frac{1-P(t=1982)}{P(t=1982)}$. The propensity score $P(t = 1982|x)$ is estimated by Probit, using years of education, years of potential job experience, its square, years of job tenure, and its square as explanatory variables (x).

The non-parametric estimation results for males appear in Figure 3, Panel A. A simple comparison of the 1982 and 2002 distributions reveals that the distribution as a whole shifted to the right and the degree of shift was larger in the upper tail of the distribution. This finding is consistent with the findings from an examination of wage growth by percentiles. However, if the workers' composition in terms of observable characteristics x was that of 1982, the wage distribution under the skill price of 2002 would have been almost identical to the actual wage distribution of 1982. This finding implies that the shift of wage distribution from 1982 to 2002 was caused by a change in workers' skill composition, while the skill price remained almost constant.

To confirm the skill upgrading of the Japanese work force and the constancy of skill price, descriptive statistics of the analysis sample and wage regression coefficients are reported in Tables 1 and 2, respectively. Table 1 reports the mean values of years of education, potential experience, and tenure. These values steadily increased between 1982 and 2002 for both males and females. The wage regression coefficients reported in Table 2 are stable over the years. If there is any change in the wage structure, the return to education falls slightly for both sexes and the experience-wage profile becomes flatter and less concave. These changes are not significant in their magnitude, though.

2.3 Supply Increase of four-year-college-graduates

The fraction of four-year-college-educated workers has increased steadily since 1982, as reported in Table 1, but the degree of increase is not uniform across age groups. Figure 4 summarizes the four-year-college-advancement rate that is defined as the number of students start attending four-year-colleges divided by the number of junior-high school graduates three years before.[10]

The male and female four-year-college advancement rates move almost in parallel except for during the period of 1976 to 1990. The male and female college advancement rates increased in parallel from 1954 to 1975. This steady increase was caused by the Ministry of Education's policy change,

[10] Roughly speaking, the Japanese education system consists of six years of primary school, three years of junior high school, and three years of high school. After graduating from high school, students have the choice to advance to a four-year-college, a two-year junior college, or an occupational training school.

which expanded college capacity under pressure from politicians and industry leaders, as documented by Pempel (1973).[11]

The four-year-college advancement rate for males had declined steadily during the period of 1976 to 1990, while the trend for females was almost stable. During this period, the Ministry of Education became reluctant to expand college capacity because of its limited fiscal ability. In particular, beginning in 1976, the Ministry cut its subsidies to private universities that accepted more students than the official capacity (Higuchi (1994)). At the same time, the population of 18-year-olds increased because the second generation of baby boomers reached adulthood around this time.

The college advancement rate increased again after 1991. This is mainly because of the deregulation of the college standards set by the Ministry. Right after the deregulation, the college capacity expanded tremendously, while the population of 18-year-olds steadily declined throughout the period.

This college advancement rate implies that its fluctuation was exogenously created by the Ministry's higher education policy and the population of 18-year-olds. In a further analysis, we exploit this fluctuation of the college advancement rate as an exogenous supply shift of college-educated workers.

[11] An exception is the sudden jump in 1964 because the 1946 cohort is smaller than adjacent cohorts as a result of the war.

3 Explaining the Trend in the Return to Education

This section attempts to identify the shift of the relative demand curve of skilled workers to unskilled workers based on skill price and quantity information. A further analysis focuses particularly on the wage differential between four-year-college-graduates and high-school-graduates because the number of four-year-college-graduates increased exogenously between 1982 and 2002, and this exogenous supply shift is useful for identifying the demand shift.

The analysis in this section utilizes the relative wage of college-graduate workers to high-school-graduate workers among male workers, while the relative quantity of college-graduate and high-school-graduate workers is based on both sexes. The wage information is based on male workers to avoid complication caused by male-female wage differentials, and quantity information is based on both sexes to capture the importance of the growth of the female labor supply during the analysis period. These treatments are consistent with Card and Lemieux (2001) and Autor et al. (2008).

3.1 Trends in the Quantity and Price of Educated Workers

We first overview the trends in the quantity and price of four-year- college-graduate workers relative to high-school-graduate workers. The wage of four-year-college-graduate workers relative to high-school-graduates is calculated for workers who exactly graduated from four-year-colleges and high schools. In contrast, the quantity of four-year-college-graduates is the sum of four-year-college-graduates and the fraction of two-year college or technical college-graduates, while high-school-graduates is the sum of high-school-graduates and the fractions of two-year college-graduates and junior-high school graduates. The fractions used in the aggregation of different educational backgrounds is based on the wage regression applied for the pooled data between 1982 and 2002.[12] The quantity is measured by (average work-hours per week) × (average annual workdays/52) × (number of workers).

Figure 5, Panel A summarizes the relative quantities of four-year-college-graduates to high-school-graduates by age cohorts. For all age cohorts, the relative quantities of college-graduates to high-school-graduates increases, but the rates of increase are substantial for the age cohorts between 40-49. This rapid increase contrasts with the stagnation of the age 30-39 cohort. This non-uniform increase of the relative supply of college-graduates is the product of a non-monotonic trend of the college advancement rate.

The quantity of four-year-college-graduates relative to high-school-graduates varies because of the compositional change of the population's educational

[12] To obtain the fraction, $\ln(wage)$ is regressed upon the junior-high school, junior/technical college, four-year-college dummy variables and eight age group dummy variables. The estimated coefficient for the junior-high school dummy variable is used to calculate the high-school equivalent quantity of junior-high school graduates. The coefficient for the junior/technical college dummy variable is used to assign its quantity to the high-school category and four-year-college-graduate category.

background, employment rate by education group, and average annual number of work hours. Among these variations, the hours of work and employment rate can be affected by demand factors through the wage rate.

The ratio of the quantity of four-year-college-graduates and high-school-graduates is decomposed as:

$$\ln(L_{cjt}/L_{hjt}) = \ln(N_{cjt}/N_{hjt}) + \ln(P_{cjt}/P_{hjt}) + \ln(\bar{h}_{cjt}/\bar{h}_{hjt}), \qquad (2)$$

where L_{ijt} stands for the total quantity of education group i, age group j in year t; N stands for the number of individuals; P stands for participation rate; and $\bar{h}$ stands for the average annual number of work-hours. Figure 5, Panels B to D report the log difference of the number of four-year-college-graduates and high-school-graduates, average number of annual work-hours for each group, and employment rate for each group. An examination of trends shows that much of the variation of the log difference in quantity is induced by a variation of the number of four-year-college-graduates relative to high-school-graduates. This finding arguably assures that the quantity of four-year-college-graduates relative to high-school-graduates is induced by the government's higher-education policy and the cohort's number of 18-year-olds.

Figure 5, Panel E reports the trends of the wage differential between four-year-college-graduates and high-school-graduates. The wage differentials basically become more narrow for all age cohorts, although the degrees of decline differ across age cohorts. The wage differential declined substantially for the age 40-49 cohort, but it stayed almost constant for the age 30-39 cohort. The location of each age cohort is in the reverse order of the relative supply. This could be interpreted as evidence for the imperfect substitution between age cohorts.

These skill-price movements over time within an age cohort nicely correspond to the relative supply trends reported in Panel A. The wage differential dropped for the age cohorts where the relative supply increased. In contrast, for the age 30-39 cohort, whose relative quantity remained constant, the wage differential increased slightly.

3.2 Method

We further analyze the demand shift for skilled workers relative to unskilled workers by controlling for the effect of the relative supply change on the wage structure. To attain this goal, we assume that firms maximize profit under a certain production technology and that this behavior generates our observations.

We assume that there are many firms in the market and each firm has a technology that is represented by the production function:

$$Q_t = [(\theta_{ct} L_{ct})^\eta + (\theta_{ht} L_{ht})^\eta]^{\frac{1}{\eta}}, \ \eta \leq 1, \tag{3}$$

where Q_t is the output in year t, L_{ct} is the aggregated labor input of college-graduates in year t, and L_{ht} is that of high-school-graduates. The parameters θ_{ct} and θ_{ht} represent the efficiency of college-graduate and high-school-graduate labor forces, respectively. The SBTC is represented by the increase of θ_{ct}/θ_{ht}. The elasticity of substitution between college-graduates and high-school-graduates is expressed as $\sigma_e = 1/(1-\eta)$.

The aggregated labor inputs for college-graduates and high-school-graduates are also presented in the CES form:

$$L_{ct} = [\sum_j (\alpha_j L_{cjt}^{\rho})]^{\frac{1}{\rho}} \tag{4}$$

and

$$L_{ht} = [\sum_j (\beta_j L_{hjt}^{\rho})]^{\frac{1}{\rho}}, \tag{5}$$

$\rho \leq 1$, where j is the index for age cohort. The elasticity of substitution between age groups is $\sigma_a = 1/(1-\rho)$.

We assume that the product price is given as unity. From the firm's profit maximization condition, we obtain:

$$\frac{w_{cjt}}{w_{hjt}} = (\frac{L_{ct}}{L_{ht}})^{\eta-1}(\frac{\theta_{ct}}{\theta_{ht}})^{\eta}(\frac{L_{cjt}}{L_{hjt}}/\frac{L_{ct}}{L_{ht}})^{\rho-1}\frac{\alpha_j}{\beta_j}. \tag{6}$$

By taking the log, we can derive the estimated equation as follows:

$$\ln(\frac{w_{cjt}}{w_{hjt}}) = (1-\frac{1}{\sigma_e})\ln(\frac{\theta_{ct}}{\theta_{ht}}) + \ln(\frac{\alpha_j}{\beta_j}) - (1/\sigma_e)\ln(\frac{L_{ct}}{L_{ht}}) - (1/\sigma_a)[\ln(\frac{L_{cjt}}{L_{hjt}}) - \ln(\frac{L_{ct}}{L_{ht}})]. \tag{7}$$

When workers of different ages are perfectly substitutable (i.e. $\sigma_a = \infty$), the term $[\ln(\frac{L_{cjt}}{L_{hjt}}) - \ln(\frac{L_{ct}}{L_{ht}})]$ drops. The effect of SBTC (i.e., change in θ_{ct}/θ_{ht}) on relative wage is small when college-graduates and high-school-graduates are close substitutes (i.e., σ_e is close to 1). Relative productivity of four-year-college-graduates to high-school-graduates, α_j/β_j, is constant across age groups if the speed of human capital accumulation is constant for both groups of graduates. The estimation equation includes age-group dummy variables to allow for the difference in the speed of skill accumulation.

As articulated by Card and Lemieux (2001), estimating (7) is difficult because it includes the aggregate labor supply index $(\frac{L_{ct}}{L_{ht}})$ that depends on parameter values, α_j, β_j and ρ (or σ_a). To overcome this difficulty, we estimate the model by several steps. The equation (7) can be written as:

$$\ln(\frac{w_{cjt}}{w_{hjt}}) = d_t + d_j - (1/\sigma_a)\ln(\frac{L_{cjt}}{L_{hjt}}), \tag{8}$$

where d_t and d_j are time and age-group dummy variables. From this equation, the elasticity of substitution across age groups, σ_a, is identified.

From the first-order condition of firms' profit maximization, we obtain

$$\ln w_{cjt} + \frac{1}{\sigma_a}\ln L_{cjt} = \ln\{[(\theta_{ct}L_{ct})^\eta + (\theta_{ht}L_{ht})^\eta]^{1/\eta-1}\theta_{ct}^{\eta-1}L_{ct}^{\eta-\rho}\} + \ln(\alpha_j) \tag{9}$$

and

$$\ln w_{hjt} + \frac{1}{\sigma_a}\ln L_{hjt} = \ln\{[(\theta_{ct}L_{ct})^\eta + (\theta_{ht}L_{ht})^\eta]^{1/\eta-1}\theta_{ht}^{\eta-1}L_{ht}^{\eta-\rho}\} + \ln(\beta_j). \tag{10}$$

Because the first terms in the above two equations depend only on time, the regressions of left-hand-side variables on year and age group dummy variables identify the parameters α_j and β_j for each j.

With the knowledge of σ_a, α_j, and β_j, the equation of interest (7) can be estimated. We parameterize the SBTC as $(1 - \frac{1}{\sigma_e}) \ln(\theta_{ct}/\theta_{ht}) = \gamma \times trend$. The parameter γ is the reduced-form measure of SBTC.

The relative quantity of four-year-college-graduates to high-school-graduates can be endogenous because it can be a response to the relative wage change. As discussed in the previous section, the relative labor quantity can be decomposed into the relative population, relative hours of work, and relative participation rate. Among these components, the relative population of college-graduates to high-school-graduates can be considered as exogenous because the fraction of people in a cohort who graduate from a four-year-college is mainly determined by the government's higher-education policy and the cohort's population. Thus we exploit the relative population of four-year-college-graduates to high-school-graduates as an instrumental variable for the relative labor quantity of four-year-college-graduates to high-school-graduates.

3.3 Results

Table 4 reports the estimation results for the regression to identify the elasticity of substitution across age groups, σ_a. Column 1 reports the results of the OLS estimation. The estimate implies that the elasticity of the substitution between age groups within a same educational category is around 6.0. The IV estimation results reported in Column 2, which treats the college/high-school labor hour ratio endogenously and uses the college/high-school population ratio as an instrumental variable, renders a slightly larger coefficient in absolute value for the college/high-school ratio (slightly smaller elasticity of substitution) and the implied elasticity of substitution is about 4.7. The estimates for the elasticity of substitution across age groups is close to the Noro and Ohtake (2006) estimate of 5.8.

With the estimate of the elasticity of substitution across age groups, the auxiliary regression models are estimated to identify the age-specific productivity parameters, α_j and β_j. The regression results are reported in the Appendix Table 1.

With the estimated values for σ_a, α_j, and β_j, we estimated the equation (7) to additionally identify the elasticity of substitution between educational groups and the time trend for SBTC.

The estimation results appear in Table 5. The estimated elasticity of substitution across educational groups is estimated rather imprecisely by both OLS and IV. A comparison of the OLS and IV estimates suggests that the OLS estimator could be biased upward, and this is consistent with our prior expectation; we were concerned with the upward bias induced by the increased college/high-school labor quantity ratio in response to the increased college/high-school wage ratio. The estimated coefficients for the aggregate supply indexes are imprecise because these indexes are linearly trending, as shown in Figure 6, and highly co-linear with the time trend that presumably captures SBTC.

The implied elasticity of substitution ranges from 0.78 to 1.50, depending on the estimation method. These estimates are slightly smaller than the estimate reported by Autor et al. (2008) for the US, which is 1.57. The coefficient for the time trend implies that the wage gap would have grown at 3.6 percent to 6.3 percent per year if the supply of college-graduates relative to high-school-graduates remained constant. However, we should note that the elasticity of substitution across education groups and the coefficient for the linear time trend are both imprecisely estimated. These results are consistent with those of Noro and Ohtake (2006), who found a statistically nonsignificant elasticity of substitution across education groups and the time trend. We must admit that the distinction between the effect of the increase of relative aggregate supply of skilled workers and technological progress is very difficult. Under the assumption that technological progress is linearly trending, only the non-linear increase of relative aggregate supply of college-graduates identifies the elasticity of substitution between college-graduates and high-school-graduates.

Overall, the estimation results weakly suggest that the wage gap between college and high-school-graduates would have dispersed if the supply of college-graduates relative to high-school-graduates had been constant between 1982 and 2002. Before concluding that the Japanese economy has experienced SBTC, we need more direct evidence of it.

4 Evidence on Skill-Biased Technological Change

The analysis in the previous section weakly suggests that the wage differential between college-graduates and high-school-graduates would have increased if the relative supply had been constant during the period between 1982 and 2002. This section complements the previous analysis by examining the direct implication of the SBTC based on the methods of Berman et al. (1994), Doms et al. (1997), Autor et al. (1998), Sakurai (2001) and Sasaki and Sakura (2004). These methods are industry-level analyses that correlate the relative increase of skilled worker input and the increase of computer input.

Suppose that a specific industry is more heavily affected than other by information technology innovation. If this innovation is SBTC, this industry attracts more skilled workers given the smooth mobility of workers across industries while the return to skill is identical across industries. Thus the degree of penetration of information technology in a specific industry is positively correlated with the increase of high-skilled workers to unskilled workers if the innovation in information technology is SBTC.

Based on the annual survey of manufacturing between 1979 and 1987, Berman et al. (1994) found that industries with heavy investment in computers had increased the share of high-skilled workers' wage bills. Doms et al. (1997) obtained similar findings based on plant-level data, although their fixed-effects results cast doubt on the causality running from computer investment to skill upgrading. Autor et al. (1998) also analyzed industry-level data covering all industries and found that computer investment-intensive industries experience growth in the wage-bill share of high-skilled workers. Sakurai (2001) applied the Berman et al. (1994) method to Japanese data on manufacturing between 1987 and 1990 and found that heavy investment in computers resulted in an increase of the wage bill share of skilled workers. Sasaki and Sakura (2004) also found that R&D investment as well as industry-level product import and foreign direct investment increased the wage bill share of college-graduate workers.

We take a similar approach, which is to estimate the following equation:

$$\Delta_{02-82} HighSkillShare_i = \beta \Delta_{02-82} Computer_i + u_i, \qquad (11)$$

where i is industry index and Δ_{02-82} is an operator to take the difference between 2002 and 1982.

The dependent variable $HighSkillShare$ represents the input ratio of high-skilled workers to low-skilled workers measured by the wage bill, work-hours, or number of workers. These dependent variables are created from the microdata of the Employment Status Survey (ESS).

The explanatory variable $\Delta_{02-82} Computer_i$ is the measurement of the increase of computer usage in the industry between 1982 and 2002. The increase is measured by two indexes. The first index is the average IT investment per total work-hour over the sample period. The amount of IT-related investment is taken from the Japan Industry Productivity 2006 (JIP 2006) database compiled by the Research Institute of Economy, Trade and Industry (RIETI). The JIP database reports the real value of the annual investment in IT-related equipment, and this value is divided by total work-hour input to the industry. The industry classifications of the ESS and the JIP databases are different, and therefore we make an adjustment to create 36 industry classifications.

The second index is the fraction of workers using a computer at work. This information is taken from the Japan General Social Surveys, 2002, a household-based interview survey that collects information from about 2,800 individuals for each survey year.[13] The survey includes a question asking whether the respondent uses a computer at work.[14] We calculate by industry the fraction of workers who use a PC at work. Similar to the JIP database, the industry codes of the JGSS do not match those of the ESS. We created 17 industry codes found in both JIP and ESS. We assumed that no one used a PC at work in 1982.

Industries with a high proportion of high-skilled workers at the initial

[13]The Japanese General Social Surveys (JGSS) are designed and carried out at the Institute of Regional Studies at Osaka University of Commerce in collaboration with the Institute of Social Science at the University of Tokyo, under the direction of Ichiro Tanioka, Michio Nitta, Noriko Iwai, and Tokio Yasuda. The project is financially assisted by a Gakujutsu Frontier Grant from the Japanese Ministry of Education, Culture, Sports, Science and Technology for the 1999-2008 academic years, and the datasets are compiled and distributed by the SSJ Data Archive, Information Center for Social Science Research on Japan, Institute of Social Science, the University of Tokyo.

[14]The question for 2002 reads, "Do you use the following? Choose all that apply." 1: E-mail (at work) 2: E-mail (Private) 3: PC (at work) 4: PC (at home) 5: Internet shopping or banking 6: Internet stock trading 7: Cellular phone 8: Fax.

point are likely to experience a lower growth rate in that proportion. These same industries may have experienced a rapid penetration of information technology, as implied by Doms et al. (1997), based on establishment-level data. To deal with this possibility, we control for the initial proportion of high-skilled workers and estimate the following equation:

$$\Delta_{02-82} HighSkillShare_i = \beta \Delta_{02-82} Computer_i + \gamma HighSkillShare_{i82} + u_i, \tag{12}$$

where $HighSkillShare_{i82}$ is the fraction of high-skilled workers in 1982.

The results of the estimation using IT investment as an explanatory variable appear in Table 6. Columns 1 - 3 are estimation results that use several measures of the ratio of four-year-college-graduate workers to high-school-graduate workers as the dependent variables. Regardless of the choice of dependent variable, the estimation results consistently indicate that IT investment is not correlated with an increase in the fraction of high skilled workers.

The regression results that are conditioned on the initial fraction of High-skilled workers reported in Columns 4 - 6, however, indicate that a greater investment in information technology is correlated with an increase of the fraction of four-year-college-graduates to high-school-graduates. All the regression coefficients are statistically significant regardless of the measurement of the proportion of four-year-college-graduates to high-school-graduates.

Table 7 reports the regression results that use the proportions of those using a PC at work as the independent variable. The results are quite similar to Table 6; the regression results without the initial proportion of four-year-college-graduates to high-school-graduates indicate that the penetration of IT is not correlated with an increase in the proportion of four-year-college-graduates to high-school-graduates at the industry level. However, once that initial proportion of 4- year college-graduates to high-school-graduates is conditioned for, the proportion of those using a PC at work in 2002 is positively correlated with the increase of the proportion of four-year-college-graduates to high-school-graduates.

Overall, the industry-level analysis indicates that the penetration of IT is positively correlated with an increase in the relative quantity of high-skilled to low-skilled workers, once the initial high-skilled to low-skilled ratio is conditioned for. Given the identical initial input level of high-skilled relative to low-skilled, the more rapidly an industry adopts IT usage, the more rapid is the growth of the relative usage of high-skilled to low-skilled workers. These findings do not contradict the SBTC hypothesis.

5 Conclusion

This paper examined the change in Japan's wage distribution between 1982 and 2002 based on microdata from the Basic Survey of Employment Structure. An examination of the difference between the 90/50 percentiles and 50/10 percentiles reveals that wage distribution was stable during this period. If there was any change of wage distribution, workers at the upper tail of the distribution experienced more wage gain during the period. This change, however, is because of skill upgrading of workers at the upper tail of the distribution, as indicated by the DiNardo et al. (1996) decomposition. If the distribution of observed skills had been that of 1982, then the wage distribution in 2002 would be almost identical to the actual wage distribution in 1982. This implies that skill prices were almost constant during the period. The stability of skill price found in the previous studies (Genda (1998), Shinozaki (2002) and Kambayashi et al. (2008)) is confirmed based on Employment Status Survey that covers not only full-time regular workers, but also part-time or non-regular workers.

We explained this stable-skill price based on a simple demand and supply framework, focusing on the stable return to education. We first noted that the non-monotonic increase of the college-advancement rate was mostly caused by the government's higher-education policy and the population of each cohort.

An estimation of technology parameters based on the CES production function, which allows for imperfect substitutability between education groups and age cohorts, revealed that college-graduates and high-school-graduates are imperfectly substitutable and that workers belonging to different age categories are imperfectly substitutable. Moreover, the estimation results consistently indicate that the wage gap between college-graduates and high-school-graduates would have increased if the relative supply of college-graduates had been constant. This implies that Japan experienced SBTC between 1982 and 2002.

Additional industry level analysis indicates that the speed of IT adoption and skill upgrading are positively correlated. This evidence suggests that the residual increase of the wage gap between four-year-college-graduates and high-school-graduates had been caused by the SBTC represented by information technology.

In sum, both the supply and demand of college-graduates relative to high-school-graduates increased between 1982 and 2002. The degrees of these shifts were almost identical, and consequently the equilibrium skill price remained stable. Thus, the stable wage distribution of Japan is not necessarily a counter example to SBTC. Once the supply increase of skilled workers slows, the skill price in Japan should start increasing.

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Table 1: Descriptive Statistics of the Data Set for the Mincer Wage Equation Estimation

Panel A: Male

Variable	1982	1987	1992	1997	2002
log (Hourly Wage)	7.43	7.56	7.84	7.96	7.84
	(0.64)	(0.66)	(0.68)	(0.68)	(0.73)
Education	11.74	12.01	12.21	12.49	12.65
	(2.42)	(2.42)	(2.41)	(2.40)	(2.38)
Experience	23.62	24.31	25.38	25.41	26.54
	(13.66)	(13.74)	(14.39)	(14.62)	(14.69)
Tenure	14.63	15.13	15.68	15.79	16.45
	(11.43)	(11.75)	(12.38)	(12.68)	(13.53)
# of Obs.	280986	273907	345390	328204	285690

Panel B: Female

Variable	1982	1987	1992	1997	2002
log (Hourly Wage)	6.85	6.99	7.25	7.40	7.38
	(0.70)	(0.70)	(0.70)	(0.69)	(0.71)
Education	11.42	11.69	11.94	12.24	12.47
	(1.99)	(1.96)	(1.95)	(1.93)	(1.93)
Experience	21.23	21.66	22.70	23.13	24.22
	(14.01)	(13.91)	(14.36)	(14.43)	(14.37)
Tenure	8.39	8.62	9.02	9.39	10.18
	(9.01)	(9.14)	(9.62)	(9.91)	(10.78)
# of Obs.	143766	152159	210986	203723	186911

Note: Standard deviations are in parentheses. Hourly wages are deflated by CPI.

Table 2: OLS Estimation of the Wage Equation

Panel A: Male

	(1)	(2)	(3)	(4)	(5)
	1982	1987	1992	1997	2002
Years of Education	0.092	0.093	0.094	0.086	0.085
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Experience	0.044	0.043	0.042	0.043	0.038
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Experience^2 / 100	-0.076	-0.073	-0.072	-0.072	-0.064
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Tenure	0.032	0.033	0.028	0.030	0.034
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tenure^2 / 100	-0.050	-0.052	-0.040	-0.042	-0.052
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	5.580	5.656	5.950	6.122	6.020
	(0.007)	(0.008)	(0.007)	(0.007)	(0.008)
Observations	280986	273907	345390	328204	285690
R-squared	0.27	0.27	0.27	0.28	0.24

Note: Standard errors are in parentheses.

Panel B: Female

	(1) 1982	(2) 1987	(3) 1992	(4) 1997	(5) 2002
Years of Education	0.098	0.096	0.097	0.096	0.095
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Experience	0.006	0.003	0.001	0.003	0.006
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Experience^2$ / 100	-0.019	-0.013	-0.010	-0.014	-0.015
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Tenure	0.043	0.045	0.042	0.045	0.038
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
$Tenure^2$ / 100	-0.077	-0.082	-0.072	-0.077	-0.070
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	5.479	5.622	5.896	5.985	5.933
	(0.014)	(0.014)	(0.012)	(0.012)	(0.014)
Observations	143766	152159	210986	203723	186911
R-squared	0.14	0.14	0.14	0.16	0.13

Note: Standard errors are in parentheses.

Table 3: Descriptive Statistics of the Data Set for the Relative Wage Equation Estimation: 1982, 1987, 1992, 1997, 2002.

Variable	Obs.	Mean	Std. Dev.
log (college/high relative annual hours of work)	40	-1.35	0.56
log (college/high hourly wage differential)	40	0.28	0.16
log (college/high relative population)	40	-1.54	0.59
log (college/high relative employment rate differential)	40	0.16	0.07

Table 4: Regression Models for the College/High School Log Hourly Wage Gap by Age Groups, First Stage Analysis, 1982-2002

	(1) OLS	(2) IV
Own supply	-0.17	-0.21
	(0.06)	(0.05)
1987	0.00	0.01
	(0.02)	(0.02)
1992	0.03	0.05
	(0.03)	(0.03)
1997	0.01	0.03
	(0.04)	(0.03)
2002	0.06	0.09
	(0.05)	(0.04)
25-29 years old	0.11	0.11
	(0.04)	(0.03)
30-34 years old	0.17	0.17
	(0.03)	(0.03)
35-39 years old	0.19	0.18
	(0.03)	(0.03)
40-44 years old	0.19	0.18
	(0.04)	(0.03)
45-49 years old	0.21	0.19
	(0.05)	(0.04)
50-54 years old	0.23	0.20
	(0.06)	(0.05)
55-59 years old	0.30	0.26
	(0.07)	(0.06)
Constant	-0.14	-0.19
	(0.08)	(0.07)
F value of exc. Inst. (P value)		926.29 (0.00)
Observations	40	40
R-squared	0.96	-

Note: Standard errors are in parentheses. Inverses of the estimated sampling variance of college/high school log hourly wage differentials are used as weights. IV is College graduates / High School graduates relative population.

Table 5: Regression Models for the College/High School Log Hourly Wage Gap, Second Stage Analysis, 1982-2002

	(1)	(2)
Estimation method	OLS	IV
Own supply	-0.168	-0.211
	(0.055)	(0.050)
Aggregate supply	-0.668	-1.286
	(0.548)	(0.980)
Trend	0.036	0.063
	(0.021)	(0.039)
Constant	-1.595	-2.926
	(0.945)	(1.803)
σ_A	5.95	4.74
σ_E	1.50	0.78
F value of exc. inst.		
Own supply		202.24 (0.00)
Aggregate supply		4.53 (0.02)
Observations	40	40
R-squared	0.96	

Notes: Standard errors in parentheses. Eight age groups are used for estimations. Instrument variables used in columns 2 and 4 are “aggregate population.” Inverses of the estimated sampling variance of college/high school log hourly wage differentials are used as weights.

Table 6: Computer Investment Measured by IT Investment and Demand for Skilled Workers

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: Change in College/High	Wage share	Hour share	Emp. share	Wage share	Hour share	Emp. share
Sum of IT Investment / Sum of Working Hour	0.139	0.220	0.061	0.258	0.389	0.127
	(0.117)	(0.172)	(0.058)	(0.125)	(0.184)	(0.061)
College / High in 1982	-	-	-	-0.179	-0.168	-0.189
				(0.084)	(0.082)	(0.081)
Constant	1.279	1.932	0.605	1.126	1.648	0.496
	(0.308)	(0.451)	(0.152)	(0.301)	(0.453)	(0.151)
Observations	36	36	36	36	36	36
R-squared	0.05	0.05	0.04	0.16	0.16	0.17

Note: Standard errors are in parentheses. IT investment information is obtained from the JIP Database 2006.

Table 7: Computer Investment Measured by Computer Usage and Demand for Skilled Workers

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: Change in College/High	Wage share	Hour share	Emp. share	Wage share	Hour share	Emp. share
Share of PC Users	0.184	-0.003	-0.078	2.258	2.867	1.039
	(0.656)	(0.935)	(0.317)	(1.066)	(1.790)	(0.594)
College / High in 1982	-	-	-	-0.284	-0.250	-0.287
				(0.123)	(0.136)	(0.134)
Constant	0.844	1.357	0.472	-0.674	-0.816	-0.379
	(0.295)	(0.420)	(0.142)	(0.705)	(1.247)	(0.417)
Observations	17	17	17	17	17	17
R-squared	0.01	0.00	0.00	0.28	0.19	0.25

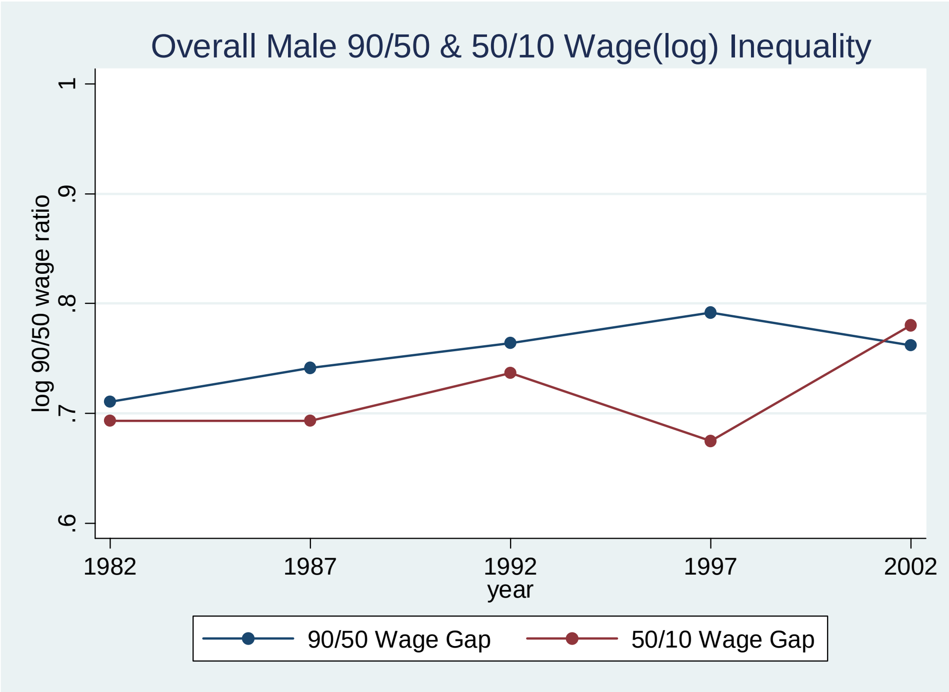
Note: Standard errors are in parentheses. PC usage share 2002 is obtained from the Japan General Social Surveys.

Appendix Table 1: Auxiliary Regression to Identify Age-specific Productivity

	(1)	(2)	(3)	(4)
	High	Coll.	High	Coll.
Method	OLS	OLS	OLS	OLS
1987	0.13	0.14	0.13	0.14
	(0.03)	(0.01)	(0.03)	(0.01)
1992	0.45	0.48	0.45	0.50
	(0.03)	(0.01)	(0.03)	(0.01)
1997	0.53	0.55	0.54	0.57
	(0.03)	(0.01)	(0.03)	(0.02)
2002	0.35	0.41	0.35	0.44
	(0.03)	(0.01)	(0.03)	(0.01)
23-24 years	9.54	9.40	10.09	9.90
	(0.03)	(0.01)	(0.03)	(0.01)
25-29 years	9.84	9.81	10.43	10.34
	(0.05)	(0.02)	(0.05)	(0.02)
30-34 years	10.03	10.05	10.61	10.59
	(0.04)	(0.02)	(0.05)	(0.02)
35-39 years	10.20	10.24	10.79	10.78
	(0.04)	(0.02)	(0.04)	(0.02)
40-44 years	10.34	10.38	10.93	10.91
	(0.04)	(0.02)	(0.04)	(0.02)
45-49 years	10.42	10.49	11.02	11.01
	(0.03)	(0.01)	(0.04)	(0.02)
50-54 years	10.44	10.53	11.03	11.04
	(0.03)	(0.01)	(0.03)	(0.01)
55-59 years	10.31	10.47	10.90	10.96
	(0.02)	(0.01)	(0.02)	(0.01)
Results Based	OLS	OLS	IV	IV
Observations	40	40	40	40
R-squared	1.00	1.00	1.00	1.00

Notes: Standard errors are in parentheses. Eight age groups are used for estimations.

Figure 1: 90/50 and 90/50 Weekly Wage Inequality, 1982-2002



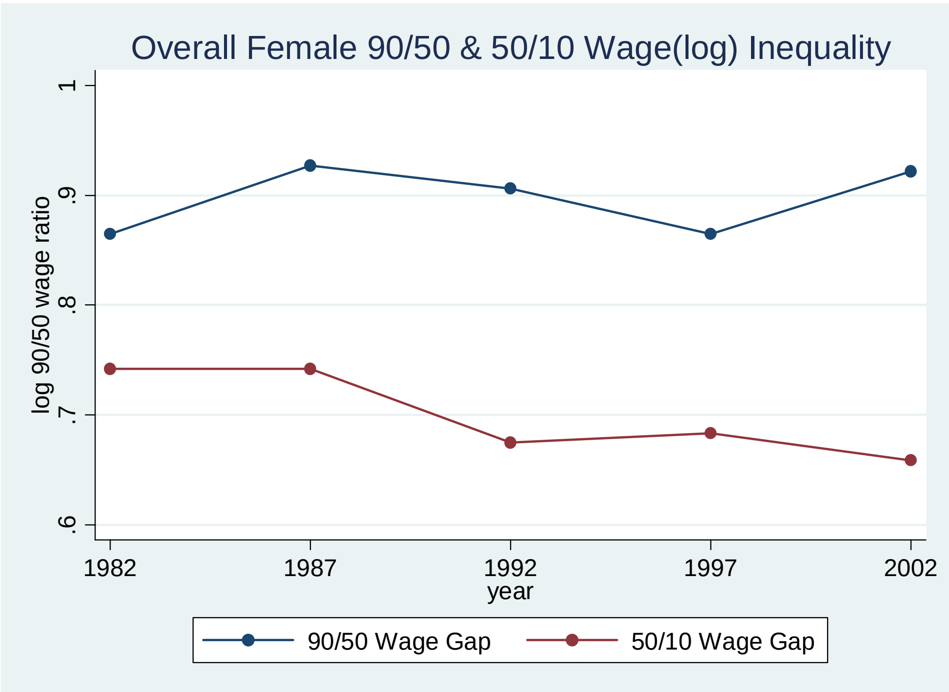
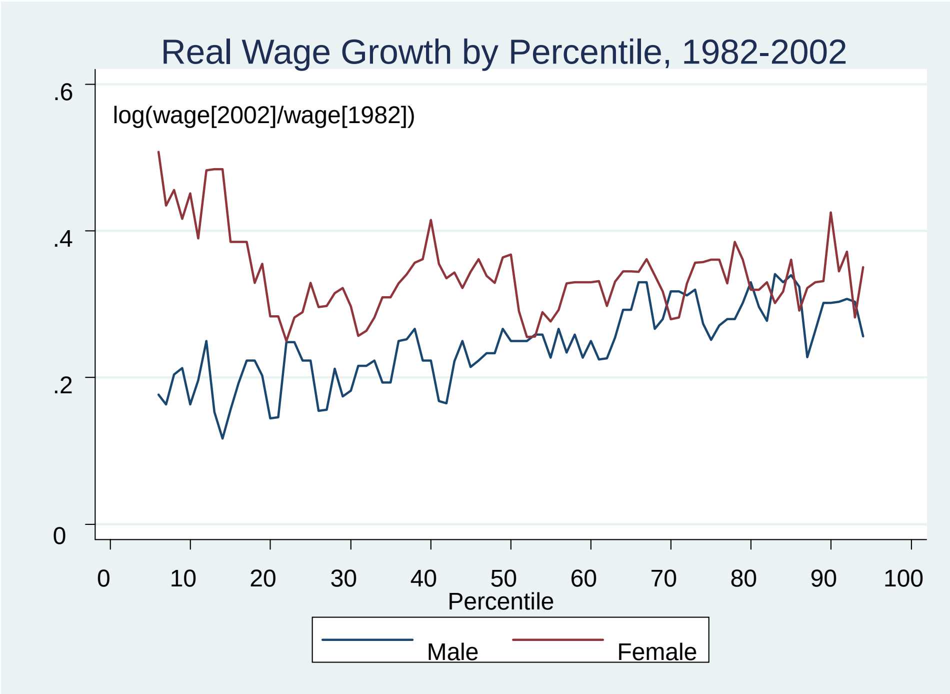
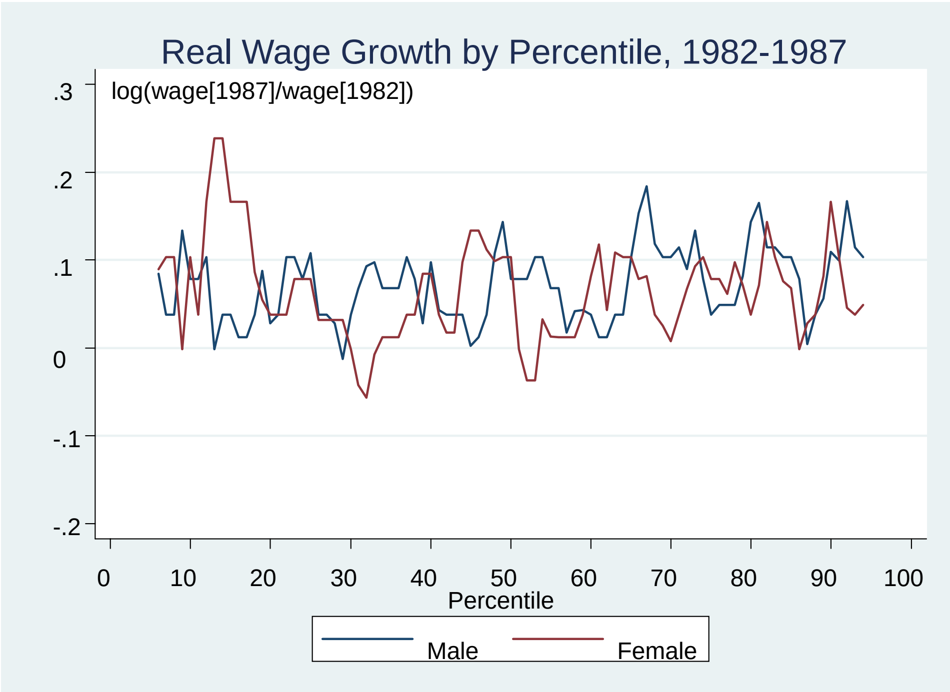


Figure 2: Wage Growth by Percentiles

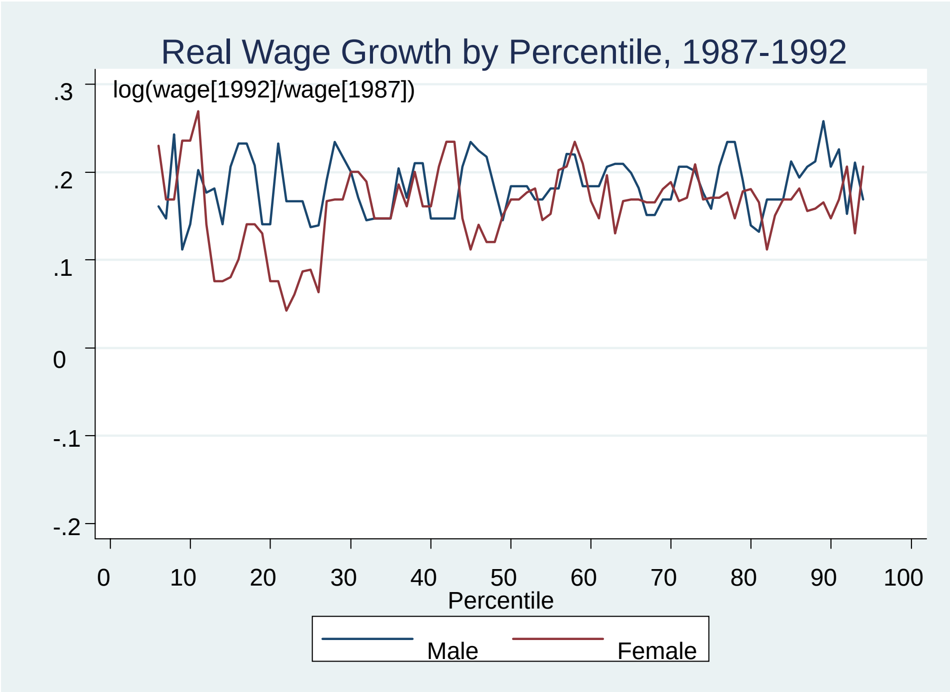
Panel A: 1982-2002



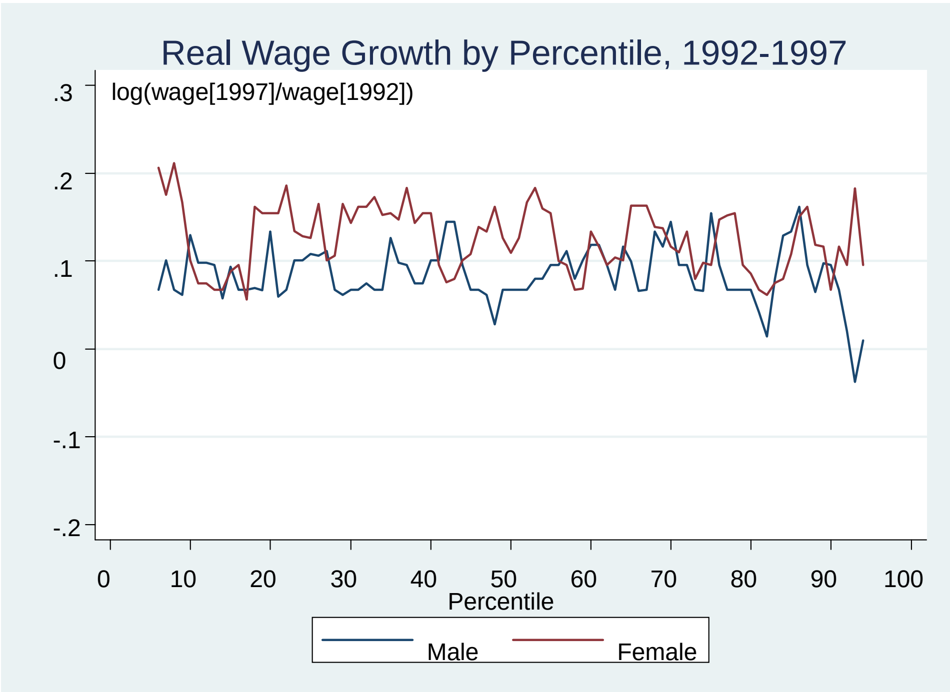
Panel B: 1982-1987



Panel C: 1987-1992



Panel D: 1992-1997



Panel E: 1997-2002

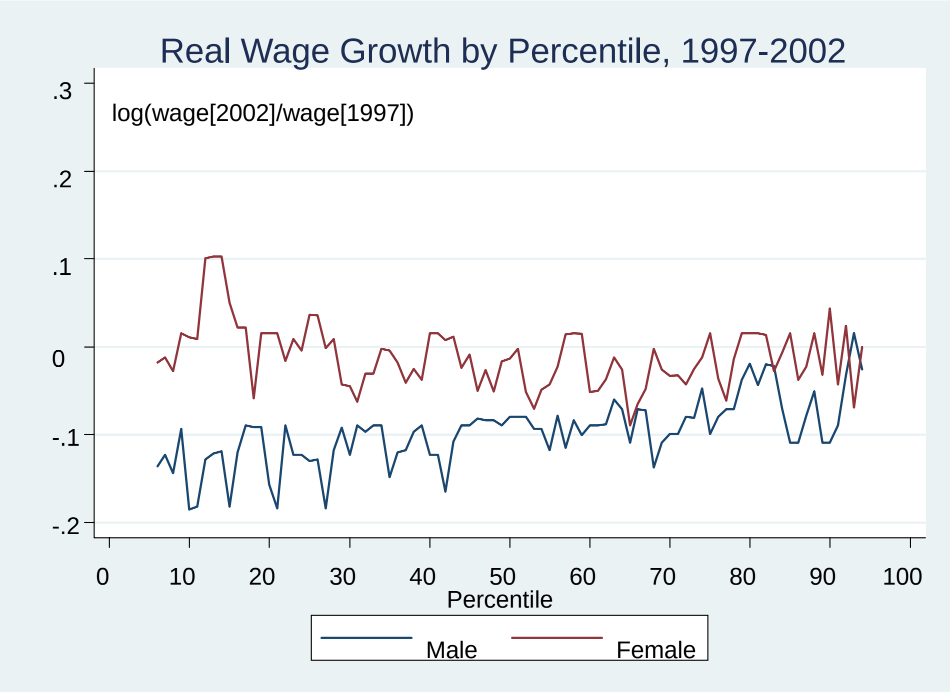
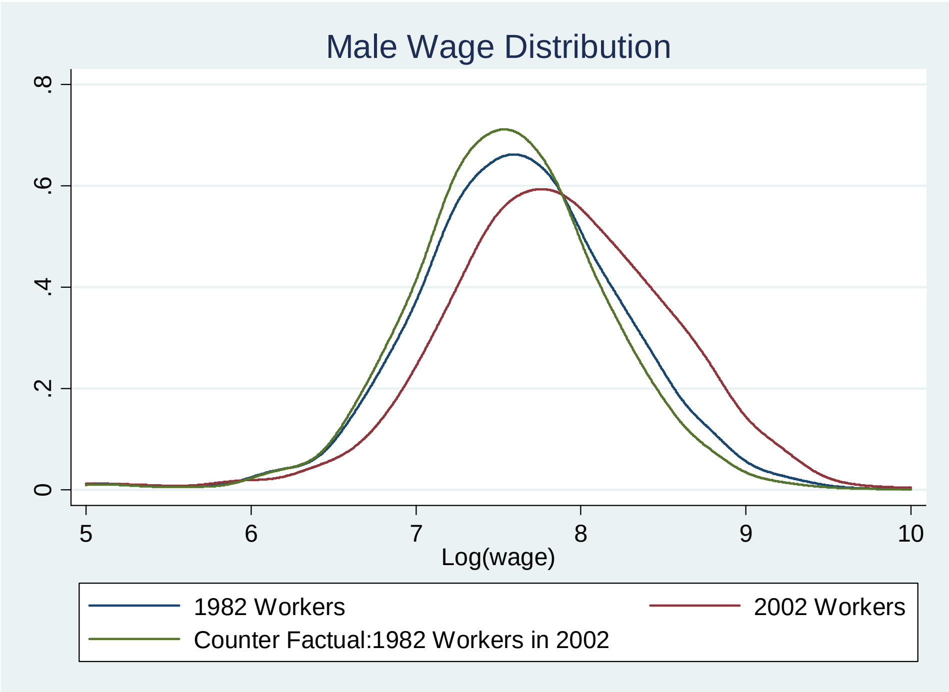


Figure 3: Kernel Density Estimation of the Wage Distribution and DFL Decomposition

Panel A: Male



Panel B: Female

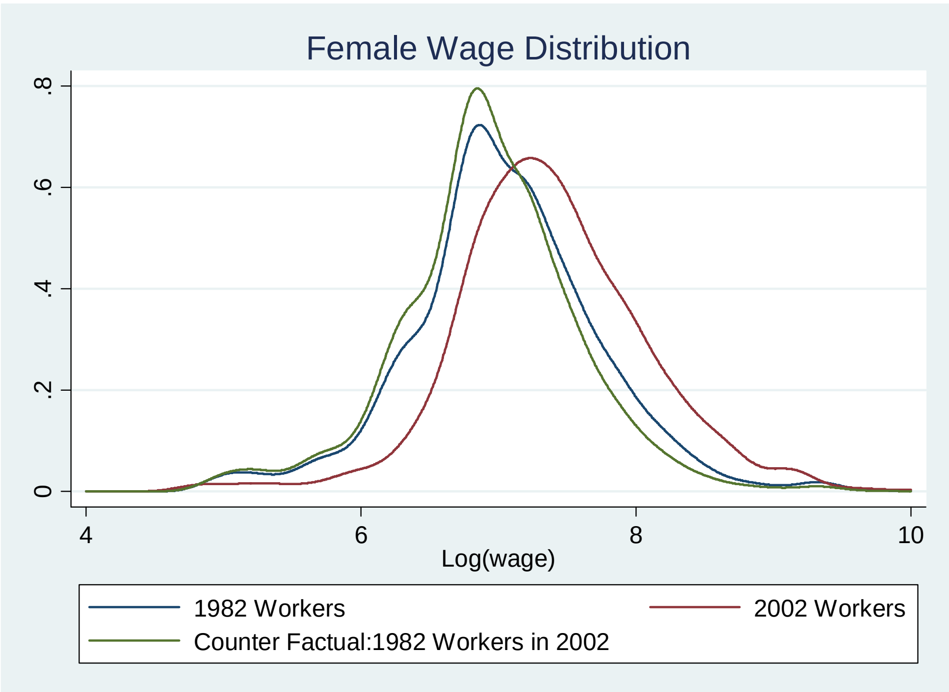


Figure 4: Post High-School Status of Graduates – Advancement Rate

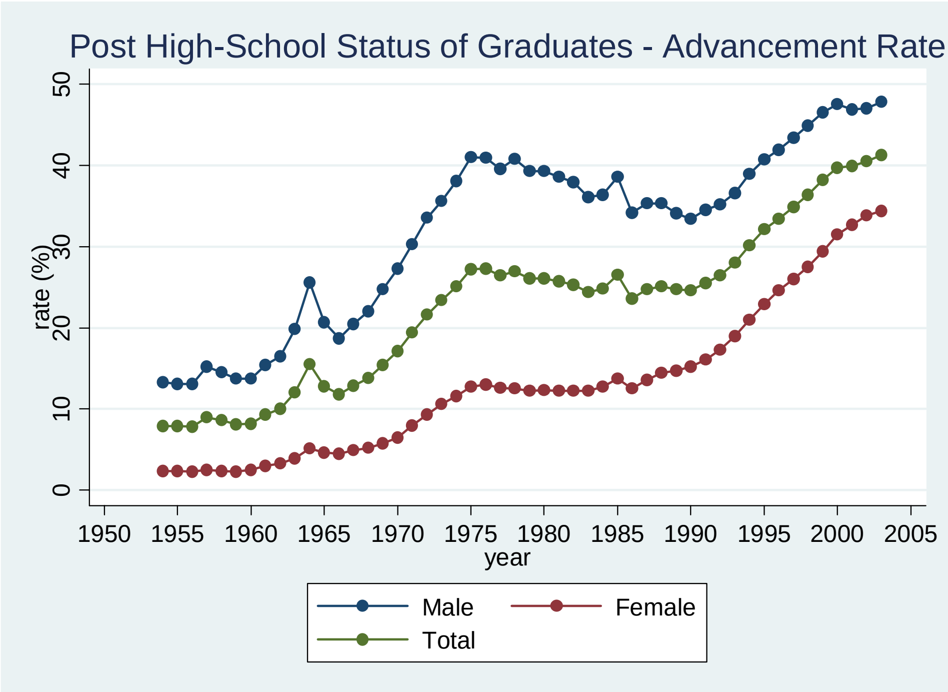
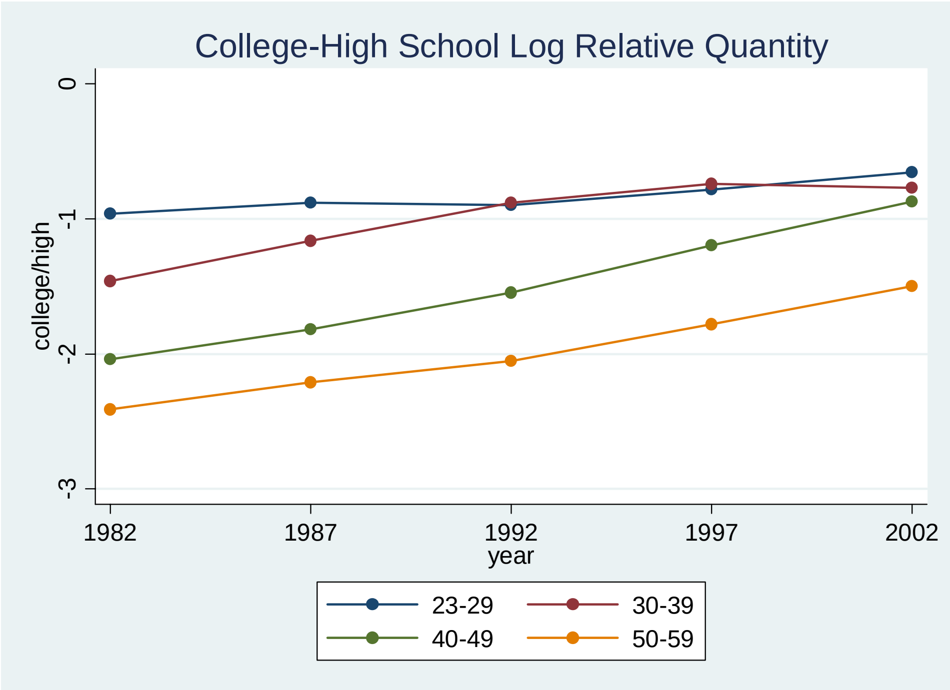
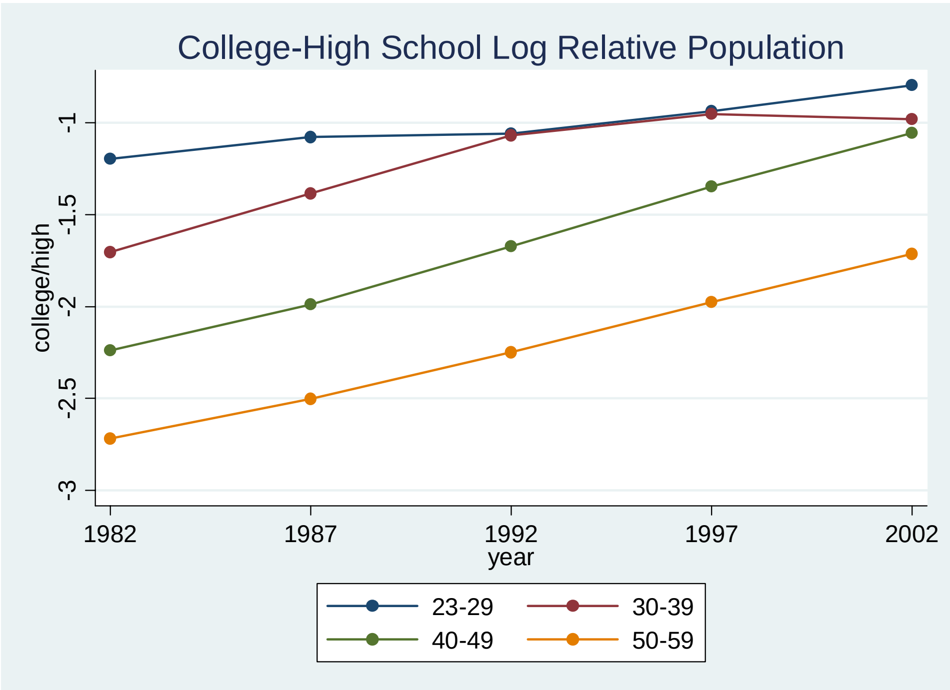


Figure 5: College/High School Relative Supply, Relative Population, Wage Differential, and Employment-Rate Differential, 1982-2002

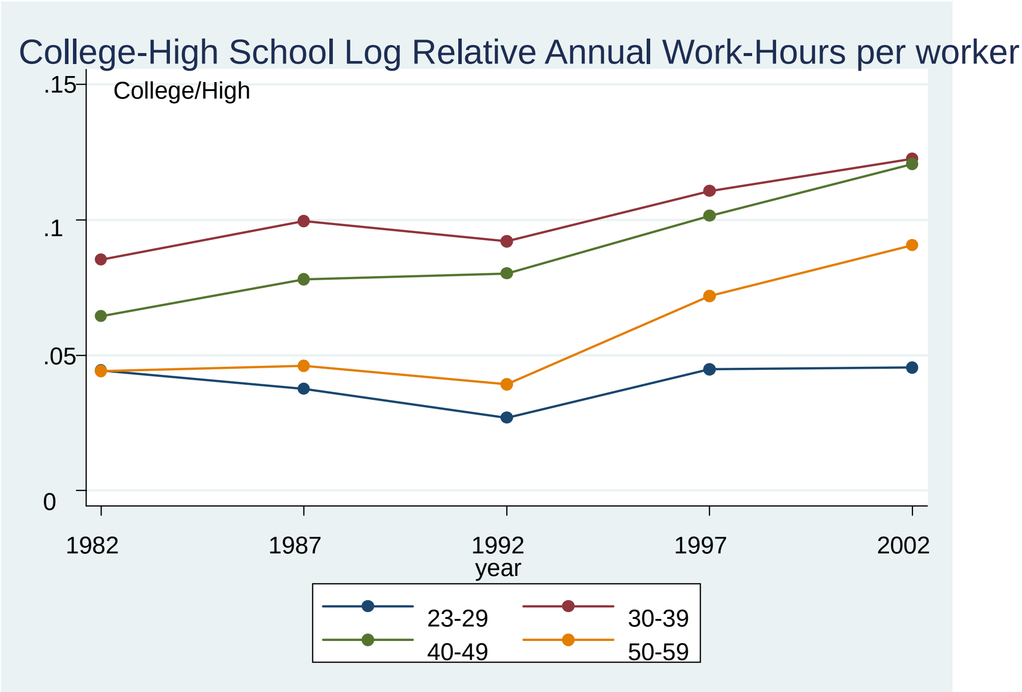
Panel A: Relative Quantity



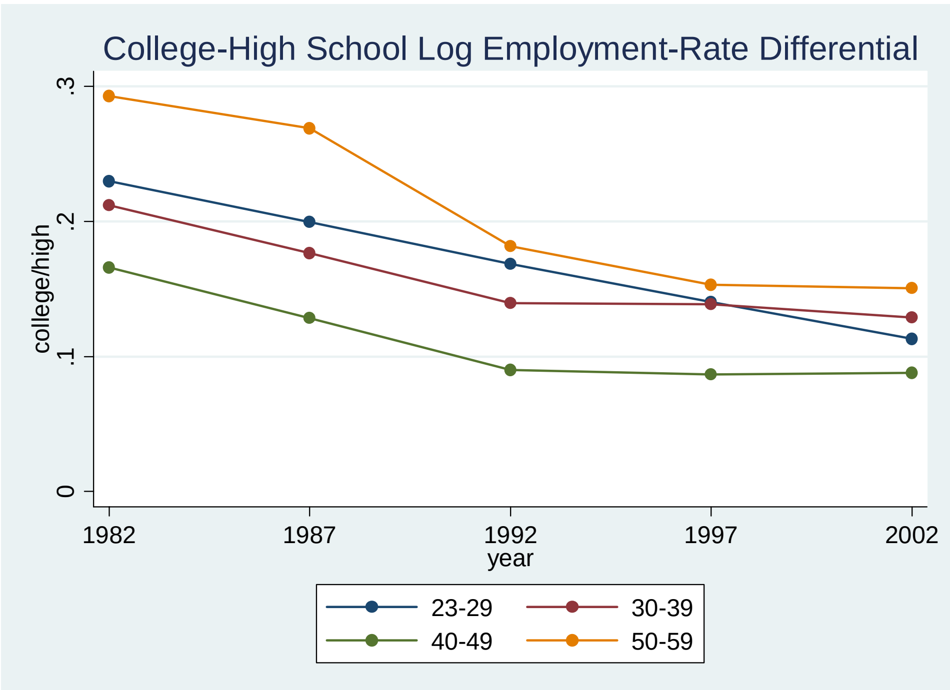
Panel B: Relative Population



Panel C: Relative Annual Hours of Work (log differential)



Panel D: Relative Employment Rate (log differential)



Panel E: Relative Wage Rate

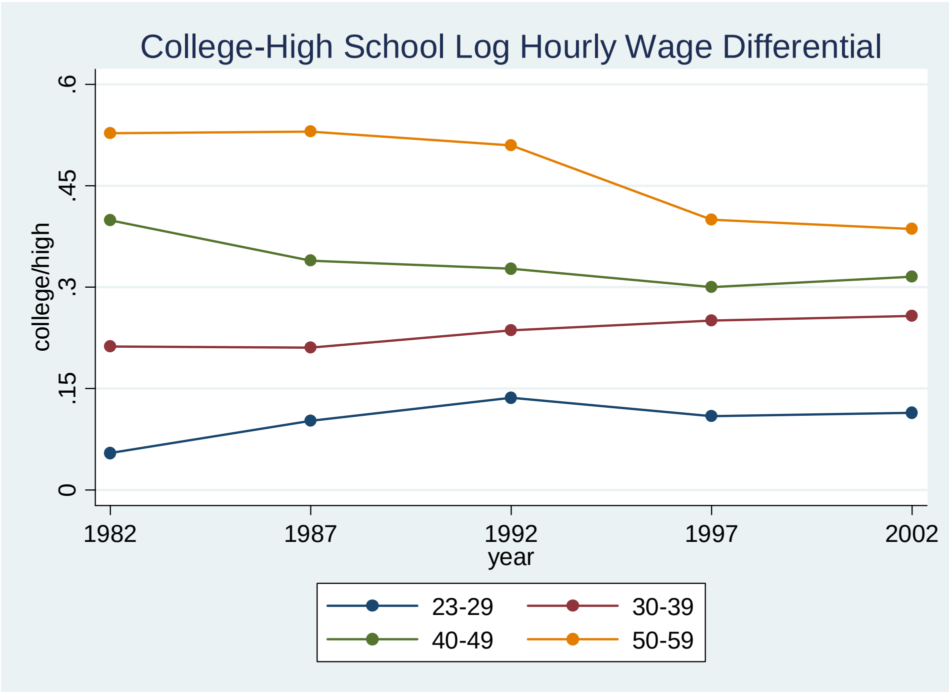


Figure 6: Trend of Wage Gap and Aggregate Supply