NBER WORKING PAPER SERIES

CHANGES IN WAGE INEQUALITY, 1970-1990

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Working Paper 5823

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
November 1996

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NBER Working Paper No. 5823
November 1996
Labor Studies

ABSTRACT

Differences in wages between skill groups declined in the 1970's and rose in the 1980's, but aggregate wage inequality grew throughout the period. This divergence remains a puzzle in recent studies of U.S. wage inequality. In this paper the sometimes divergent paths of inter-group and intra-group inequality are explained by the human capital approach. In it, wages are the return on cumulated human capital investments. In turn, interpersonal distributions of investments and of marginal rates of return on them are determined by individual supply and demand curves. Recent studies have shown that relative growth of human capital supply in the 1970's and of demand in the 1980's generated the U-shaped time pattern of ("between group") skill differentials. Argument and evidence in this paper show that a widening of dispersion among individual demand curves started in the 1970's and generated a continuous expansion of ("within group") residual wage inequality. The widening dispersion in demand curves reflects a growing skill bias in the demand for labor. Aggregate inequality grew throughout the period because within group inequality accounts for the larger part of total inequality. The data also indicate that wage inequality grew in the face of stability in the dispersion of human capital and despite the likely decline in inequality of opportunity, as reflected in the decline in dispersion among supply curves.

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1 Introduction

The past quarter century witnessed major changes in the U.S. wage distribution. Skill differentials in hourly wages due to differences in education declined in the 70's but rose sharply in the 80's (Fig 1) while differentials due to work experience rose in the 70's and remained large in the 80's. Wage differentials within education and experience groups rose throughout the 70's and 80's. The rapidly growing skill wage gap in the 80's and the increase in overall wage inequality since the 70's (Fig 2) stimulated a number of studies[1]. At first most of the studies focused on the wage structure ("between group" differentials), defined by education and working age. Subsequently a number of studies attempted to explain within group differentials, the larger part of total inequality[2].

A consensus appears to be emerging on the interpretation of changes in skill differentials in wages. These are seen as outcomes of shifts in the supply and demand for human capital with supply increases dominating in the 70's and technology driven demand growth dominating in the 80's[3]. However no clear picture emerges from the variety of hypotheses to which within group changes in wage differentials have been subjected[4]. The intuitive notion that within group differentials correspond to unmeasured skill differentials and so should move together with the educational wage differentials faces the divergent patterns of change between and within groups for part of the period[5].

The purpose of this paper is to provide a human capital analysis of both

[1]The detailed facts and findings reported in studies available up to 1992 are described comprehensively in the survey of Levy and Murnane (1992). Additional studies prior to 1995 are described by Kosters (1991) and Kodrzycki (1995).

[2]In an analysis of variance or regression sense.

[3]See e.g. Katz and Murphy (1992), and Mincer (1993).

[4]Levy and Murnane (1992); Juhn, Murphy and Pierce (1993).

[5]Levy and Murnane view this contradiction as a major puzzle in current research on the wage distribution. According to Kodrzycki the puzzle remained unresolved in 1995.

intergroup and intra-group wage inequality, measured by variances in log-wages, and their changes over time. The approach reveals that, in principle, within group inequality is not directly or closely related to between group variances, so that differential movements in the two components of inequality are possible. Understanding the course of within group inequality requires a disaggregation of group demand and supply curves of human capital to the individual level along the lines suggested by Becker (1967). It then becomes apparent that a widening dispersion among individual demand curves produced growth of within group inequality throughout the period. This widening among demand curves is independent of the rightward shifts of the supply curves in the 70's which lowered the average skill gap ("rate of return"), and of upward shifts in the demand curves which raised the average skill gap to new heights in the 1980's.

The course of inequality within groups dominated the changes in aggregate inequality since the within group variance accounts for more than half of the total variance.

2 The Human Capital Approach

Human capital theory views individual earnings w_i as the product of accumulated investment in self K_i and the rates of return r_i on them. Both vary across individuals. When the investments are measured in time units, such as years of schooling and their equivalents[6] in job training and other post-school investments the products are logarithms of wages [7]. At working age (experience) j, "capacity" (log) wages[8] of individuals i are

$$\ln w_{ij} = \alpha_{i0} + r_i K_{ij} \tag{1}$$

[6]The time-equivalent of investment K_i is the ratio of investment costs to the "capacity" earnings in the relevant period.

[7]For derivation see Mincer (1974, p.19).

[8]"Capacity" earnings do not net out costs of investments in human capital.

Here K_{ij} is accumulated human capital through period j, with r_i the same in all periods. A natural measure of wage inequality is the variance of $\ln w_i$. The term α_{i0} represents log wages of individuals without accumulated human capital, which are very low in modern industrial economies, and will be ignored for present purposes. With these assumptions the log variance in equation 1 omitting α_{i0} is

$$\sigma^2(\ln w) = \bar{r}^2\sigma^2(K) + \sigma^2(r)(\bar{K}^2 + \sigma^2(K)) \tag{2}$$

This expression derived by Goodman (1960) holds when r_i and K_i are independent. But, in cross-sections of workers the relation between r_i and K_i can be positive or negative. If the relation is positive the variance in (2) is augmented by covariation of r_i and K_i. If negative the variance is correspondingly reduced[9]. Assessing the signs and magnitude of the covariation is helpful in the analysis that follows.

It is useful for our purposes to decompose the wage distribution into sets defined by years of work experience. Aggregate wage inequality σ_T^2 is a weighted sum of variances within each experience group (j) and of wage differentials (d_j) between experience groups[10].

$$\sigma_T^2 = \sum_{j=1}^{T} \frac{n_j}{n_T}(\sigma_j^2 + d_j^2) \tag{3}$$

The weights $\frac{n_j}{n_T}$ are given by the (working) age distribution, while the d_j reflect the slope of the (log) wage experience profiles. Putting these aside for the moment, we focus on the major components σ_j^2 , the variances within experience groups.

At any level of experience, K_i the accumulated human capital of individual i measured in year equivalents consists of years of schooling s_i and

[9] Since both r_i and K_i are non-negative, the product is large when large r_i are associated with large K_i and small when small r_i are associated with small K_i. So a perfect positive correlation yields the largest range for the product while a perfect negative correlation produces the smallest range. The correlations are monotonic, not necessarily linear.

[10] d_j is the difference between the mean log-wage in group j and the overall mean.

years of post-school investments K_{pi}, so $K_i = s_i + K_{pi}$. The variance in the experience set j is therefore:

$$\sigma_j^2 = \bar{r}^2\sigma^2(s_i + K_{pi})_j + \sigma^2(r)\{\sigma^2(s_i + K_{pi}) + (\overline{s + K_{pi}})^2\} + cov(r_i, K_i) \quad (4)$$

The last term on the right denotes the covariation between r_i and K_i.

A particular experience set $\hat{j}$, at working age $\hat{j} \cong \frac{1}{r}$ termed the "overtaking" set[11] is of special interest. At that stage of experience, returns on post-school investments are cancelled by costs. Therefore wages in the overtaking set are capacity wages due to schooling alone, and the variance in (4) contains only the schooling terms as shown in (5).

$$\sigma_{\hat{j}}^2 = \bar{r}^2\sigma^2(s) + \sigma^2(r)\{\bar{s}^2 + \sigma^2(s)\} + cov(r_i, s_i) \quad (5)$$

3 Between and within schooling group inequality in the overtaking set

Because of the importance of human capital in schooling apart from training or learning on the job, we first analyze the overtaking experience group to explore the causes of differential movements between and within schooling groups. For empirical purposes we defined the overtaking set in a broad 5-year interval of 6 to 10 years of experience in order to accommodate changes in r as well as to obtain a sufficiently large sample.

A regression equation of $\ln w$ on schooling s in the overtaking set is

$$\ln w = \alpha_0 + rs_i + u_i \quad (6)$$

In this regression, the explained variance $\bar{r}^2\sigma^2(s)$ is a product of the variance of schooling and the average rate of return (squared) on it, the first right hand term in equation (5). The remainder is the within group residual variance

[11] For derivation see Mincer (1974, p.7).

$\sigma^2(u)$. The annual time series of variances in the overtaking set and of their two components $\bar{r}^2\sigma^2(s) + \sigma^2(u)$ are shown in Fig. 3. The data are from the March issues of the CPS which contain information on annual earnings and hours of work. We restricted the sample to white males, non-students with up to 40 years of work experience.

Equation (5) shows that the within group or residual inequality $\sigma^2(u)$ does not depend on the average size of the rate of return, but on its dispersion $\sigma^2(r)$ as well as on the level and dispersion of schooling, $\bar{s}^2 + \sigma^2(s)$. The term $\sigma^2(s)$ is much smaller[12](less than $\frac{1}{25}$) than the level $\bar{s}^2$. So despite its appearance in both between and within groups, $\sigma^2(s)$ does not cause a correlation between the within group and between group variances. Over time, as shown in Fig 3 the within group variance $\sigma^2(u)$ widened in the 70's while the between group variance narrowed. Both widened in the 80's but not because of the small common term $\sigma^2(s)$, which remained relatively stable throughout.

The meaning of these movements, divergent in the 70's and parallel in the 80's, become clear in the framework of demand-supply analysis patterned after Becker's distributional analysis (1967, 1975). In it individual marginal rates of return on human capital are determined by the intersection of individual demand D_i and supply S_i. For a given level of human capital D_i's differ according to workers' marginal productivity. The slopes of the D_i's are negatively inclined because of diminishing returns to investments characterizing individuals, whose overall potential is necessarily limited. For simplicity the D_i's are portrayed in Fig 4 as linear with the same slopes for each person. The levels of supply curves differ across individuals as they face different costs of investment. The linear supply curves are rising reflecting rising marginal costs as the amount of required financing increases[13]. Again the slopes are common across individuals in Fig 4.

Based on estimates in the annual CPS data, educational attainment of

[12] $\sigma^2(s)$ varied between 5.9 and 6.4, while $\bar{s}^2$ was over 155. On the scale of Fig.5 $\sigma^2(s)$ would appear quite flat.

[13] For elaboration see Becker (1967).

young cohorts including those at the overtaking stage of experience (6-10 years) increased rapidly in the 70's and stabilized in the 80's as shown in Fig 5. The increase in average schooling ($\bar{s}^2$) indicates a shift of the supply curves to the right as a result of which the average rate of return across workers fell in the 1970's as was shown in Fig 1. With $\sigma^2(s)$ relatively stable the intergroup variance $\bar{r}^2\sigma^2(s)$ fell.

If the spread among demand curves $\sigma^2(D)$ and supply curves $\sigma^2(S)$ had not changed over time we would have found a decline in the intergroup variance $\bar{r}^2\sigma^2(s)$ and some increase in the intra-group residual variance $\sigma^2(u)$ in the 70's. The increase in $\sigma^2(u)$ results in part from the increase in ($\bar{s}^2$), according to equation (7):

$$\sigma^2(u) = \sigma^2(r)\{\bar{s}^2 + \sigma^2(s)\} + cov(r, s) \tag{7}$$

The growth of schooling $\bar{s}^2$ only partly accounts for the growth of the residual variance $\sigma^2(u)$ in the 1970's. $\bar{s}^2$ increased by less than 15 per cent while $\sigma^2(u)$ increased over 30 per cent in the 1970's. In the 1980's schooling level stabilized, but $\sigma^2(u)$ continued to grow though at a somewhat slower rate.

What explains the continued growth of the within-group variance, $\sigma^2(u)$ at overtaking?

After accounting for the growth of $\bar{s}^2 + \sigma^2(s)$ in equation (5), $\sigma^2(u)$ grew either because $\sigma^2(r)$ grew or the covariance term grew, or both.

The distribution of schooling and of marginal rates of return, as determined by the intersection of D_i and S_i in Fig 4, provides insights into changes in $\sigma^2(r)$ and in $cov(r_i, s_i)$:

Denote the intercepts of the demand curves in Fig 4 by d_i and of the supply curves by c_i. Assuming linearity and common slopes b and e respectively, we have demand equations:

$$r_i = d_i - bs_i \tag{8}$$

and supply equations:

$$i_i = c_i + es_i, \tag{9}$$

where r_i is the marginal rate of return and i_i is the marginal interest cost, s_i is years of schooling. The scatter of intersections where $r_i^* = i_i^*$ yields:

$$s_i^* = \frac{(d_i - c_i)}{(b+e)}, \tag{10}$$

and, substituting into (8)

$$r_i^* = d_i - \frac{b(d_i - c_i)}{(b+e)} \tag{11}$$

Let $\frac{b}{b+e} = \gamma$, then

$$r_i^* = (1-\gamma)d_i + \gamma c_i \tag{12}$$

However, it is not the marginal r_i but the average r_{ai} that is multiplied by s_i to get $\ln w_i$, and this is the variable in equation (1) through (5). Since $r_{ai} = \frac{1}{2}(d_i + r_i)$ in our linear formulation,

$$r_{ai}^* = \frac{1}{2}\{d_i + (1-\gamma)d_i + \gamma c_i\} = (1 - \frac{\gamma}{2})d_i + \frac{\gamma}{2}c_i \tag{13}$$

and

$$\sigma^2(r_{ai}^*) = (1-\gamma)\sigma^2(d_i) + (\frac{\gamma}{2})^2\{\sigma^2(d_i) + \sigma^2(c_i)\} \tag{14}$$

We conclude from (14) that $\sigma^2(r_{ai}^*)$ increases if $\sigma^2(d_i)$ or $\sigma^2(c_i)$ or both increase[14]. Now, the linear

$$cov(r_{ai}^*, s_i^*) = cov\{(1-\frac{\gamma}{2})d_i + \frac{\gamma}{2}c_i, (d_i - c_i)\frac{\gamma}{b}\} =$$
$$\frac{\gamma}{b}\{\sigma^2(d_i) - \frac{\gamma}{2}\{\sigma^2(d_i) + \sigma^2(c_i)\}\} \tag{15}$$

[14]The $cov(d_i, c_i)$ term is omitted from(14), (15) and (16). As shown in Appendix A, its inclusion in the analysis does not change the results, when $cov(d_i, c_i) \leq 0$. Otherwise, the valid general conclusion is that $\sigma^2(d_i)$ grew faster than $\sigma^2(c_i)$ over the period.

In eq. (15) the covariance grows when $\sigma^2(d_i)$ increases, or if $\sigma^2(c_i)$ decreases while $\sigma^2(d_i)$ increases. Both $\sigma^2(d_i)$ and $\sigma^2(c_i)$ cannot decrease because that would decrease $\sigma^2(u)$.

The growth of covariance (r, s) from negative in the 70's to positive in the 1980's implies, according to eq. (15) that $\sigma^2(d_i)$ grew, while $\sigma^2(c)$ grew less or declined between the decades. Indeed, the stability of $\sigma^2(s)$ does suggest that $\sigma^2(c)$ declined while $\sigma^2(d)$ grew. This is shown by eq. (16), derived from (10):

$$\sigma^2(s_i^*) = (\frac{\gamma}{b})^2\{\sigma^2(d_i) + \{\sigma^2(c_i)\} \qquad (16)$$

As we see in (14) and (15) an increase in $\sigma^2(d_i)$ and a similar decrease in $\sigma^2(c_i)$ is consistent with increases in $\sigma^2(r)$ and in the covariance $cov(r_{ai}, s_i)$ between the decades.

The data suggest that $cov(r_{ai}^*, s_i)$ was negative and barely changed in the 70's, but it turned positive and grew strongly in the 80's.

The evidence is provided by the coefficient of s^2 in the wage function which includes a quadratic term for schooling. If $cov(r_i^*, s_i^*) \neq 0$, a regression of r_{ai}^* on s_i is

$$r_{ai}^* = \alpha_1 + \alpha_2 s_i + v_i, \quad \text{and} \quad \alpha_2 = \frac{cov(r_{ai}, s_i)}{\sigma^2(s)} \qquad (17)$$

The wage function is $\ln w_i = \alpha_0 + r_{ai}s_i + u_i = \alpha_0 + (\alpha_1 + \alpha_2 s_i + v_i)s_i + u_i$, hence

$$\ln w_i = \alpha_0 + \alpha_1 s_i + \alpha_2 s_i^2 + v_i s_i + u_i \qquad (18)$$

The sign of $cov(r, s)$ shows up as the sign of α_2 in the wage function. Annual quadratic wage functions in the overtaking set show that α was negative until the 1980's then increasingly positive. The graph in Fig 6 indicates that $cov(r, s) = \alpha_2\sigma^2(s)$ grew little in the 70's but turned increasingly positive in the 80's. According to eq. (15), a negative covariance in the 70's means that $\sigma^2(c) > \sigma^2(d)$, a greater dispersion among supply curves than among demand curves. Since 1970, however, the dispersion in demand grew, while that in supply diminished. In Becker' terminology, inequality of opportunity dominated the wage distribution to begin with, but that inequality diminished since then, while inequality in return to ability grew.

The growth of $\sigma^2(d_i)$ is consistent with a great deal of recent research that emphasizes skill or ability biased changes in the demand for human capital in the past quarter century.

The widening dispersion among micro demand curves $\sigma^2(d_i)$ throughout the period represents greater increases in demand for workers with the same measured characteristics whose human capital is more productive, while demand for less able or less skilled workers either increased less or actually declined. The growth of the covariation (r_i, s_i) of rates of return with levels of human capital is similarly interpretable as a growing human capital bias in the demand for labor.

In sum, while between (schooling) groups inequality declined in the 70's, the residual variance $\sigma^2(u)$ grew in the 70's because $\bar{s}^2$ and $\sigma^2(r)$ increased. In the 1980's the growth of $\sigma^2(u)$ came from the growth of $cov(r, s)$ and of $\sigma^2(r)$. Changes in both periods reflected increases in $\sigma^2(d_i)$. In the 1980's the increases in average demand for human capital raised the average rate of return $\bar{r}$ and increased inter-group inequality, while the widening of micro-demand curves $\sigma^2(d_i)$ continued to increase the intra-group inequality $\sigma^2(u)$.

We now extend the analysis of wage inequality to the aggregate, which according to equation (3) is a weighted sum of (log) wage variance in each experience group j, and of intergroup differences in mean wages.

4 The Aggregate as a set of Experience Groups

The variance σ_j^2 at a fixed level of experience j can be written, rewriting equation (4):

$$\sigma_j^2 = \{\bar{r}^2\sigma^2(s) + \sigma^2(r)[\bar{s}^2 + \sigma^2(s)] + cov(r_i, s_i)\} + \{\bar{r}^2\sigma^2(K_{pi})_j +$$

$$+\sigma^2(r)[\bar{K}_{pi}^2 + \sigma^2(K_{pi})]_j + cov(r_i, K_{pi})\} =$$

$$= \sigma_{\hat{j}}^2 + \sigma^2(r_i K_{pi}) \tag{19}$$

A term omitted for the sake of simplicity is the $cov(s_i, K_{pi})$ which affects $\sigma_{\hat{j}}^2$ positively but need not change over time. The first right hand component of (19) is the variance at "overtaking". The second component represents the contribution of post school investments and of their variance to σ_j^2 . It can be calculated as $\sigma_j^2 - \sigma_{\hat{j}}^2$. Aggregate inequality σ_T^2 is, by eq. (3) and eq. (7):

$$\sigma_T^2 = \sum_j \frac{n_j}{n_T}\{\sigma_{\hat{j}}^2 + \sigma^2(r_i K_{pi})\} + \sum_j \frac{n_j}{n_T} d_j^2 =$$
$$= \sigma_{\hat{j}}^2 + \sum_j \frac{n_j}{n_T}\sigma^2(r_i K_{pi}) + \sum_j \frac{n_j}{n_T} d_j^2 \tag{20}$$

According to equation (20), aggregate inequality is equal to the inequality at overtaking, augmented by the contribution of post-school investment variances and of the steepness of experience wage profiles-both weighted by the (working) age distribution.

We can calculate the contribution of each right hand term to the aggregate variance, using measures of σ_T^2, $\sigma_{\hat{j}}^2$ and $\sum_j \frac{n_j}{n_T}\sigma_j^2$ as follows:

$$\sigma_T^2 = \sigma_{\hat{j}}^2 + \left(\sum_j \frac{n_j}{n_T}\sigma_j^2 - \sigma_{\hat{j}}^2\right) + \left(\sigma_T^2 - \sum_j \frac{n_j}{n_T}\sigma_j^2\right) \tag{21}$$

Variances σ_j^2 at 8 experience levels were calculated year by year from CPS data covering 40 years of work experience of the employed male work force. The experience levels are in 5-year intervals. The experience profiles of the 8 variances σ_j^2 are shown in Table 1 in columns 1 to 8, for years 1970, 1980, and 1990. With the exception of the initial experience level (col.1), the σ_j^2 increase with experience up to group 5 or 6, and decelerate thereafter, in all periods.

As explained in (Mincer, 1974)the growth of these variances with experience reflects the cumulation of net post-school investments[15]. Deceleration sets in when the investments terminate in the third decade of experience.

Table 1 shows that the increase of inequality with experience is much slower in 1980 than in 1970, while in 1990 it is twice as rapid as in 1970.The difference in growth rate of these variances in 1970, 1980 and 1990 are attributable to differences in inv estment volumes K_{ji} at given j, and/or differences in r_j. The declines in r and K_j from 1970 to 1980, and their increase in the 80's are plausible in view of observed changes in rates of return to schooling, as rates of return to human capital are likely to move together over time in schooling and in job training. The decline in r resulting from the rapidly increasing supply of educated workers in the 1970's very likely reduced the demand for job training[16] But even if volumes of job training were unaffected - no direct information is available - the decline in r is a sufficient explanation of the differing ra tes of growth of variances in the decade periods.

In inspecting the variances σ_j^2 for $j \geq 2$ we see (in Table 1 and Fig 7, for $j = 5$) that $(\sigma_j^2 - \sigma_{\dot{j}}^2)$, the contribution of inequality in returns to job training $\sigma_j^2(r_i K_{pi})$ shows a U shaped p attern over time (1970 to 1990), with bottom in 1980. Reflecting these findings for each level of experience the contribution of inequality in returns to post-school investments to aggregate inequality, the second right hand term in (21) calculate d by the second term in (21), is also U-shaped. This is shown in Table 2 col.3.

Table 2 shows the aggregate variance (col.1) and its decomposition, by

[15]The simplest explanation (Mincer, 1974 p. 101) is by the process $\ln w_{j+1} = \ln w_j + rk_j$, lnw_j grows with j, and so does $\sigma^2(\ln w_j) = \sigma^2(\ln w_{j-1} + rk_{j-1})$, so long as $k_j > 0$ and $r > 0$, unless $cov(\ln w_j, rk_j)$ is strongly negative.

[16]For differing view s on this matter, see Welch (1979), Berger (1985). See also Mincer (1994), especially Table 10.

eq.(12) and (13), with $\sigma_j^2 = \bar{r}^2\sigma^2(s) + \sigma^2(u)$

$$\sigma_T^2 = \underbrace{\bar{r}^2\sigma^2(s)}_{I} + \underbrace{\sigma^2(u)}_{II} + \underbrace{\sum_j \frac{n_j}{n_T}\sigma^2(r_i K_{pi})}_{III} + \underbrace{\sum_j \frac{n_j}{n_T} d_j^2}_{IV} \qquad (22)$$

Component

I is the variance due to schooling wage differentials

II is the residual variance at overtaking, reflecting differentials within schooling groups

III is the variance component due to differences in returns to post-school investments

IV is the contribution of between experience group wage differentials, which reflect the steepness of the average wage profile.

The last component $\sum_j \frac{n_j}{n_T} d_j^2$ is not U-shaped. It doubles from 1970 to 1980 and remains at the 1980 level in 1990. As was shown in the literature (Welch 1979, Berger 1985,Mincer 1994), the wage profiles steepened in the 1970's because of the rapid growth of young cohorts ("baby boomers") in the labor force.

If skill groups are defined by educational and post-school(e.g. job training) investments, the course of between group inequality is shown in Table 2 by components I+III+IV representing the sums of variances of the schooling (I) and post-school components,(III) and (IV). Components I and III declined in the 70's, and rose in the 80's, as did rates of return. Component IV which reflects the slopes of wage profiles rose in the 70's and stabilized in the 80's, largely as a result of demographic change. The within group variance (component II) grew in the 70's and in the 80's, for reasons analyzed in section 3 above.

Since individual post-school investments (K_{pi}) are not observed, the observed within group variance is the sum of components II and III. This also grows monotonically over time, because $\sigma^2(u)$ grows continuously, while $\sum_j \frac{n_j}{n_T}\sigma^2(r_i K_{pi})$ is U-shaped but relatively small. The between group variance is now the sum of components I and IV and shows little change in the 70's, but growth in the 80's.

The difference in behavior of the variance in group 1 and group 2, seen in Table 1 and Fig 8 provides additional information: The difference is positive and shows a continuous decline over calendar time. Since $\ln w_1 = \ln w_2 - k_1$, where k_1 are post-school investments at initial experience levels, and w_2 are wages at overtaking, that is capacity starting wages.

$$\sigma_1^2 = \sigma_2^2 + \sigma^2(k_1) - 2cov(\ln w_2, k_1) \tag{23}$$

Small or negative covariances make for the excess $\sigma_1^2 - \sigma_2^2 > 0$. This difference declined as the covariance in equation (23) grew over time[17].

Here a continually rising covariance term would indicate that postschool investments rose more or declined less for workers with higher capacity wages which reflect schooling or ability within schooling groups. This is consistent with a growing skill bias in the demand for labor, the conclusion reached in the closer examination of developments in the overtaking set in section 3.

5 Summary and Conclusions.

Aggregate inequality in wage rates of male workers increased since the 1970's after decades of relative stability. At the same time measured skill differentials in wages such as educational wage differentials narrowed in the 70's and increased more strongly in the 80's. The discrepancy between changes in aggregate and in "between group" inequality is explained mainly by the

[17]An alternative, not mutually exclusive possibility is a decline in $\sigma^2(k_1)$. It is less plausible in view of the growth of training in the 1980's. The growth of $cov(\ln w_2, k_1)$ suggests also that $cov(s_i, k_{pi})$ which was omitted in equation (19) contributed to the growth of σ_j^2 over time.

growth since 1970 of "within group" or residual inequality which accounts for more than half of aggregate inequality.

Why did residual (within group) inequality change over time differently from the skill gap in wages? The question is answered in a human capital approach. The formulation points to a distinction between movements of sets of individual demand and supply curves for human capital and changes in dispersions within the sets of D_i's and S_i's. The shifts in levels are responsible for between group changes in wage inequality, while changes in dispersions within the sets produce changes in within group inequality.

When groups are defined by education, the decline in the skill wage differentials in the 70's is due to an increase in relative supplies of educated workers with static average demand for human capital. The opposite is true in the 80's. But while supply curves shifted in the 70's and demand curves in the 80's, dispersion among the demand curves kept widening throughout the period. This resulted in continued growth of residual inequality. The widening dispersion across micro demand curves represents increasing skill bias in the demand for human capital.

Empirical evidence was shown that residual inequality in the overtaking set $\sigma(u)$ grew since 1970, because all components of it grew. This implies a widening dispersion in the demand curves, thus providing evidence for the skill bias as the cause of increasing within group inequality.

By itself the widening inequality among demand curves $\sigma(D)$ may not reflect a skill bias, if it were due merely to a random reshuffling of D_i over time, i.e. if $cov(d_{i,t-1}, d_{i,t}) = 0$. This is negated by the evidence on growing correlation between levels of human capital and rates of return (e.g. the growth of the $cov(r_i, s_i)$) and of the growing covariance between post-school investments and levels of human capital, as inferred from the changing differences among successive σ_j^2 in the 70's and 80's.

In the 70's the variance in demand curves was smaller than the variance in the supply curves. But the latter declined over the period, while the variance in the set of demand curves continued to grow. In Becker's terminology inequality of opportunity dominated the inequality in ability prior to the 80's, but the latter grew in relative importance over the period, while the former either declined or grew at a lesser pace. That the growing importance of cognitive (or information and communication) skills underlie this transformation is attested by other studies as well[18].

When within group inequality is defined as the residual from the wage function applying to the aggregate wage distribution, or to higher levels of experience, an added component of the residual is due to the variance of post-school investments across workers. Because of changes in the rate of return r, this component $\sigma(r_i K_{pi})$ behaves like the between schooling group component $\sigma(r_i s_i)$, that is it has a similar u shaped pattern over time. However it is a relatively small part of aggregate residual inequality which therefore does not affect its persistent increases over time although it slows its pace in the 70's.

This analysis applies to the wage rates of males. Other studies have shown that patterns of change in total inequality were the same as described here for the female and total labor force, as well as for annual and weekly earnings as compared to wage rates. Levels and changes in inequality are more pronounced in earnings as variance in hours adds to the variance in wage rates even without a significant correlation between wages and hours. Actually, as the skill gap widened over time, hours of work fell for the less skilled. The positive correlation in changes in hours and wage rates, itself evidence of shifts in demand , raised the growth of inequality in earnings further as compared to the basic inequality in wage rates, which was analyzed here.

[18]See in particular Murnane, Willet and Levy (1995).

6 Appendix A

Equations (14), (15) and (16)in the text assume that covariance $cov(d_i, c_i) = 0$ that is correlation $\rho(d_i, c_i) = 0$. Dropping this assumption changes eq. (14), (15) and (16) respectively into:

$$\sigma^2(r_{ai}) = (1 - \frac{\gamma}{2})^2\sigma^2(d_i) + (\frac{\gamma}{2})^2\sigma^2(c_i) + 2(1 - \frac{\gamma}{2})\frac{\gamma}{2}\rho(d_i, c_i)\sigma(d_i)\sigma(c_i) =$$

$$= (1 - \gamma)\sigma^2(d_i) + (\frac{\gamma}{2})^2\{\sigma^2(d_i) + \sigma^2(c_i)\} + \gamma(1 - \frac{\gamma}{2})\rho(d_i, c_i)\sigma(d_i)\sigma(c_i) \quad (14a)$$

$$cov(r_{ai}, s_i) = \frac{\gamma}{b}\{(\sigma^2(d_i) - \{\frac{\gamma}{2}\sigma^2(d_i) + \frac{\gamma}{2}\sigma^2(c_i)\} - (1 - \frac{\gamma}{2})\rho\sigma(d_i)\sigma(c_i)\} =$$

$$= \frac{\gamma}{b}\{(\sigma^2(d_i) - \frac{\gamma}{2}\{\sigma^2(d_i) + \sigma^2(c_i)\} - (1 - \frac{\gamma}{2})\rho\sigma(d_i)\sigma(c_i)\} \quad (15a)$$

$$\sigma^2(s_i) = (\frac{\gamma}{b})^2\{\{\sigma^2(d_i) + \sigma^2(c_i)\} - 2\rho\sigma(d_i)\sigma(c_i)\} \quad (16a)$$

consequently

$$2\rho\sigma(d_i)\sigma(c_i) = \sigma^2(d_i) + \sigma^2(c_i) - (\frac{b}{\gamma})^2\sigma^2(s_i) \quad (16b)$$

Substituting (16b) into (14a) we get:

$$\sigma^2(r_{ai}) = (1 - \frac{\gamma}{2})\sigma^2(d_i) + \frac{\gamma}{2}\sigma^2(c_i) - \frac{\gamma}{2}(1 - \frac{\gamma}{2})(\frac{b}{\gamma})^2\sigma^2(s_i) \quad (14b)$$

Substituting (16b) into (15a) we get:

$$cov(r_{ai}, s_i) = \frac{\gamma}{2b}\{(\sigma^2(d_i) - \sigma^2(c_i) - e^2\sigma(s_i)\} \quad (15b)$$

Note that the last right hand terms in (14b) and (15b) are constant, because $\sigma^2(s)$ was stable. According to (15b) the observed growth in the covariance

$cov(r_{ai}, s_i)$ implies a faster growth in the variance in demand for human capital $\sigma^2(d)$ than in supply $\sigma^2(c)$, with the latter possibly declining. The growth of dispersion in average rates of return $\sigma^2(r_{ai})$ is according to (14b), consistent with this implication. At the same time, the stability of dispersion in human capital $\sigma^2(s)$ implies, according to (16a) that, indeed the increase in $\sigma^2(d)$ was accompanied by a decrease in $\sigma^2(c)$, if $\rho(d_i, c_i)$ was negative. $\rho(d_i, c_i) < 0$ is a sufficient, though not necessary condition. Otherwise, the weaker conclusion is that increases in $\sigma^2(d)$ had to be greater than those in $\sigma^2(c)$, if both grew.

The plausibility of the conjecture that $\rho(d_i, c_i) < 0$ may be justified by the observation that higher income persons (and families) are more likely to face lesser marginal costs of financing investments in human capital while benefitting from more favorable home environment and better school quality: Higher demand curves (greater d_i) are thus more likely to be paired with lower supply curves (smaller c_i).

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Table 1
Experience Profiles of Variances

Years	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1970/71	0.35	0.21	0.23	0.25	0.26	0.26	0.25	0.26	0.28	0.26
1980/81	0.29	0.24	0.26	0.26	0.27	0.26	0.27	0.27	0.32	0.27
1990/91	0.33	0.31	0.35	0.37	0.38	0.37	0.39	0.40	0.42	0.36

(1) to (8) : $\sigma_j^2, j = 1,2,..8$

(9) Aggregate $\sigma_T^2(\ln w)$

(10) $\sum_j \frac{n_j}{n_T}\sigma_j^2$

Table 2
Decomposition of Aggregate Variances

Years	σ_T^2	I	II	III	IV	Between I+III+IV	Within II	Between I+IV	Within II+III
1970/71	0.28	0.05	0.16	0.04	0.03	0.12	0.16	0.08	0.20
1980/81	0.32	0.03	0.21	0.02	0.06	0.11	0.21	0.09	0.23
1990/91	0.42	0.07	0.24	0.04	0.07	0.18	0.24	0.14	0.28

$$\sigma_T^2 = \underbrace{\bar{r}^2\sigma^2(s)}_{I} + \underbrace{\sigma^2(u)}_{II} + \underbrace{\sum_j \frac{n_j}{n_T}\sigma^2(r_i \cdot K_{pi})}_{III} + \underbrace{\sum_j \frac{n_j}{n_T}d_j^2}_{IV}$$

Figure 1

Educational Wage Differentials:1/4 (lnW(college)-lnW(high school)

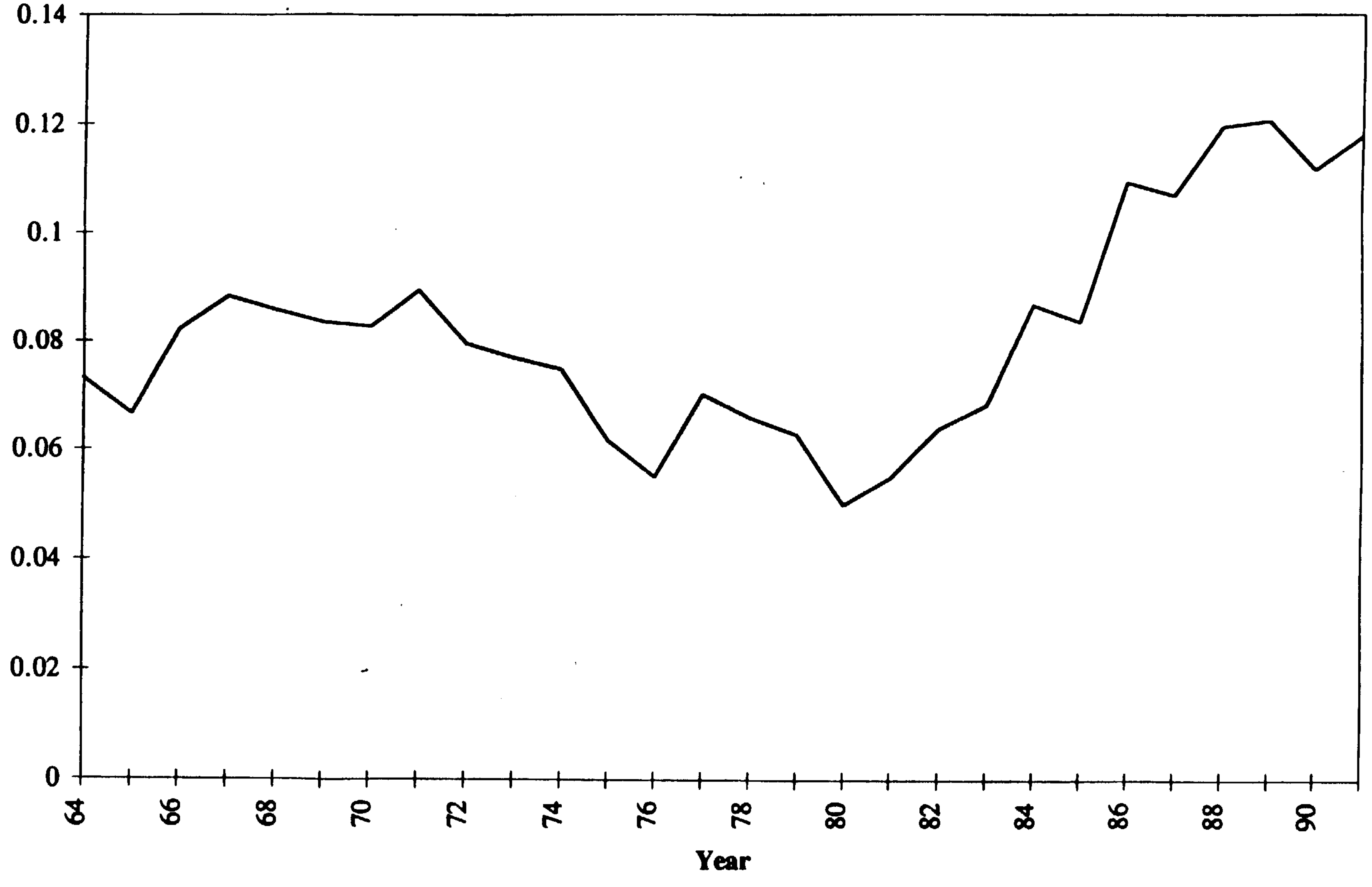


Figure 2

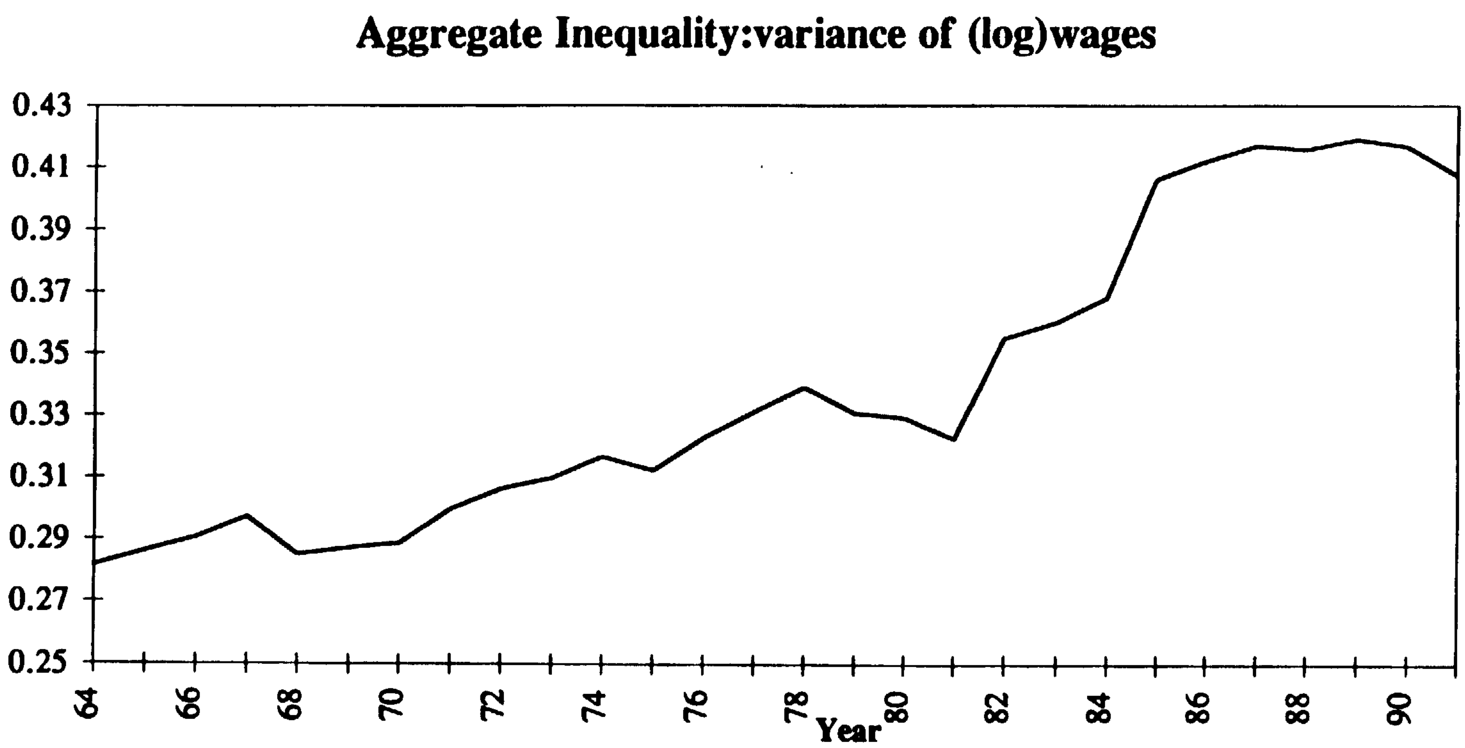

Aggregate Inequality:variance of (log)wages
0.43
0.41
0.39
0.37
0.35
0.33
0.31
0.29
0.27
0.25
64
66
68
70
72
74
76
78
80
82
84
86
88
90
Year

Figure 3

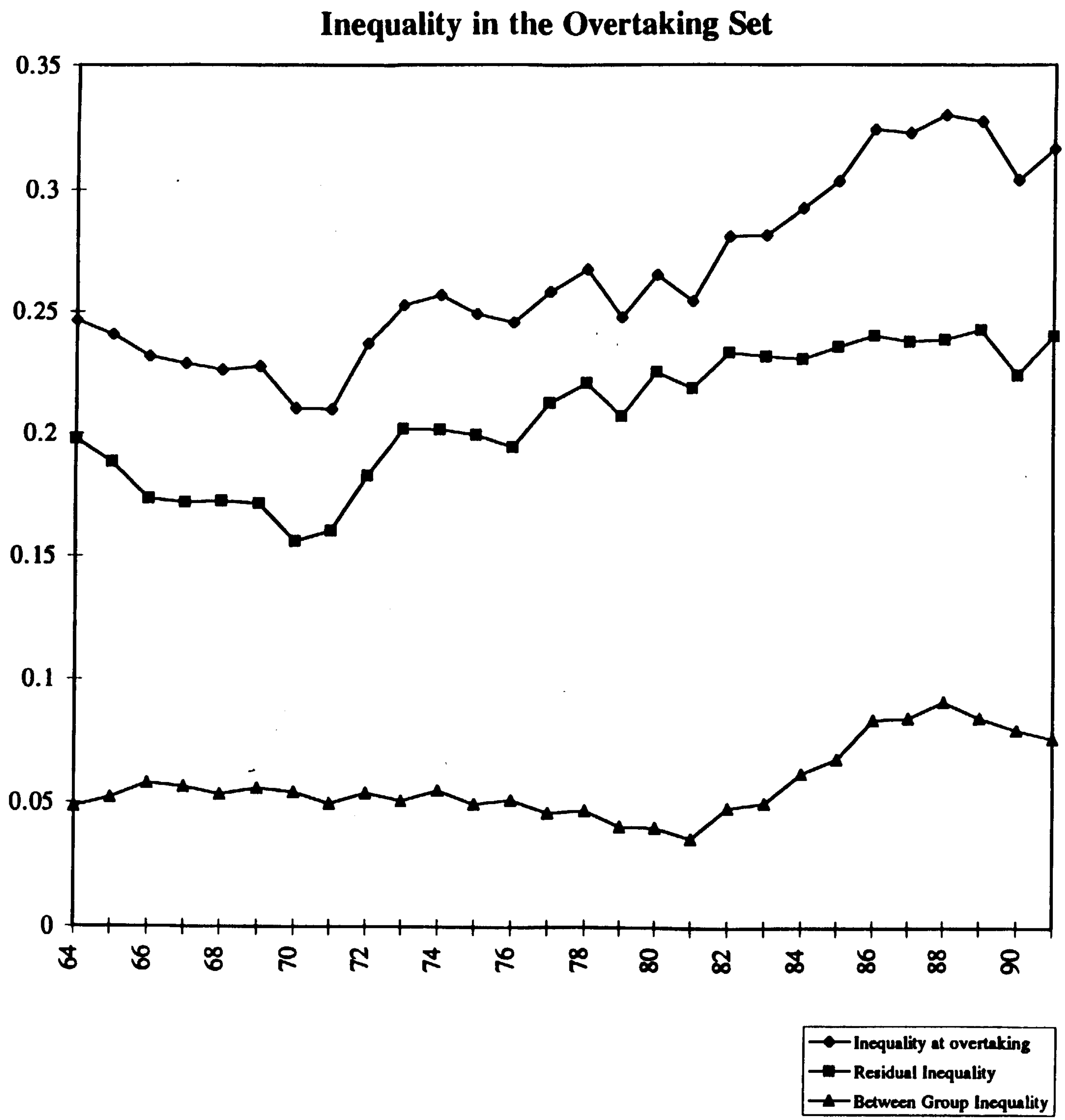

Inequality in the Overtaking Set
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
64
66
68
70
72
74
76
78
80
82
84
86
88
90
Inequality at overtaking
Residual Inequality
Between Group Inequality

Figure 4
Demand and Supply

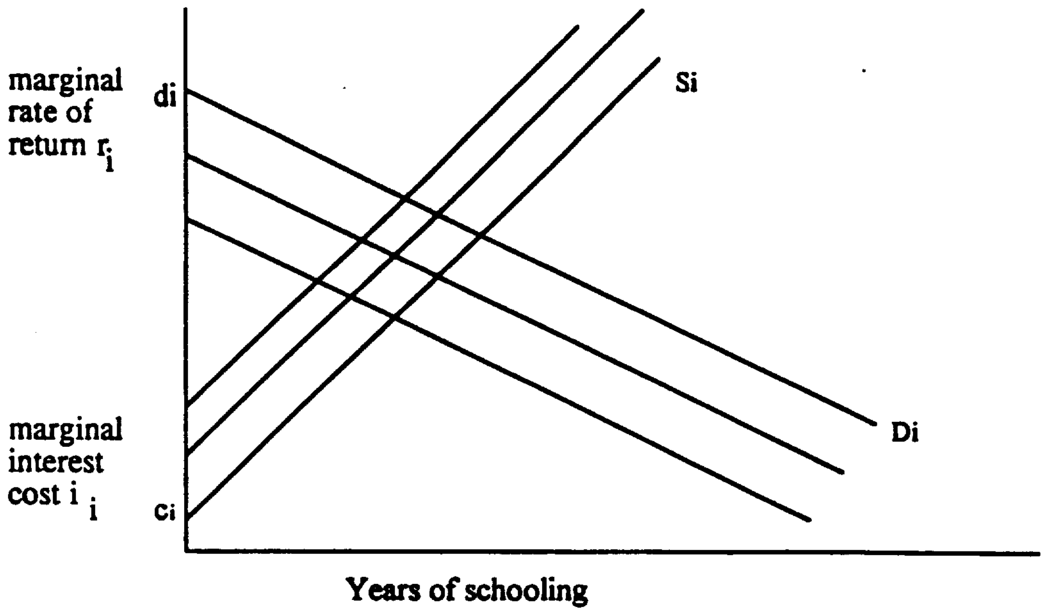


Figure 5

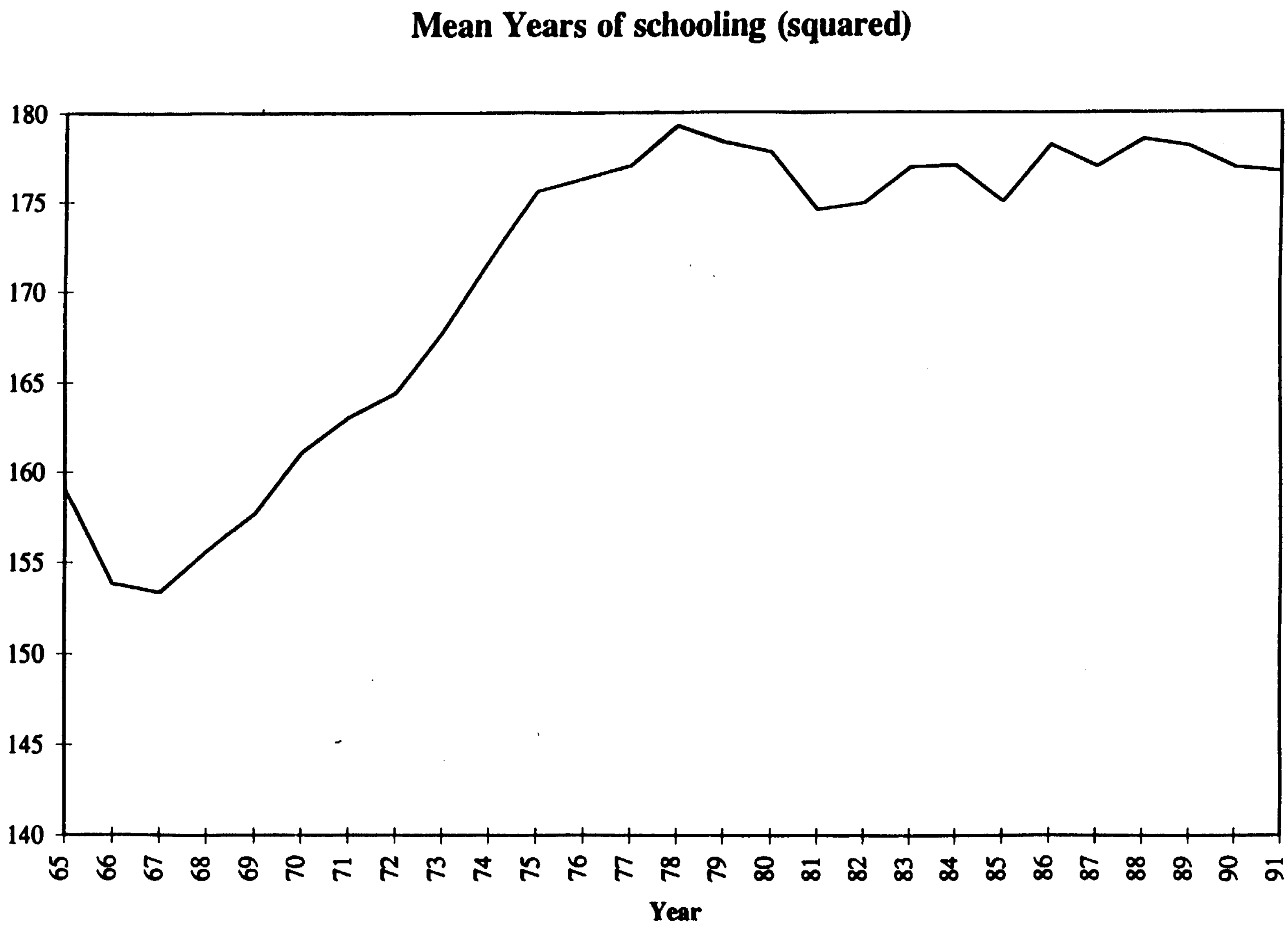

Mean Years of schooling (squared)
180
175
170
165
160
155
150
145
140
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
Year

Figure 6

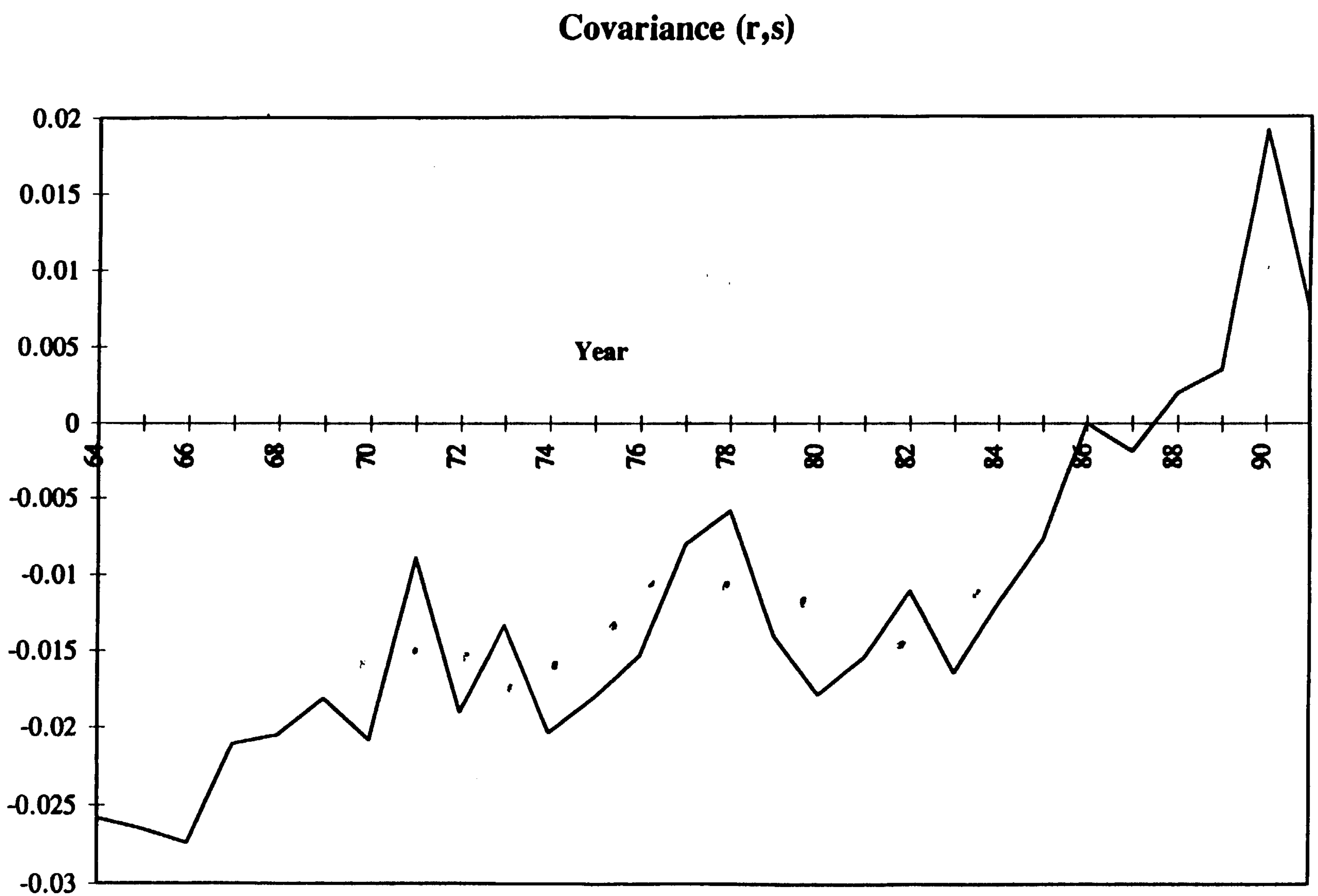
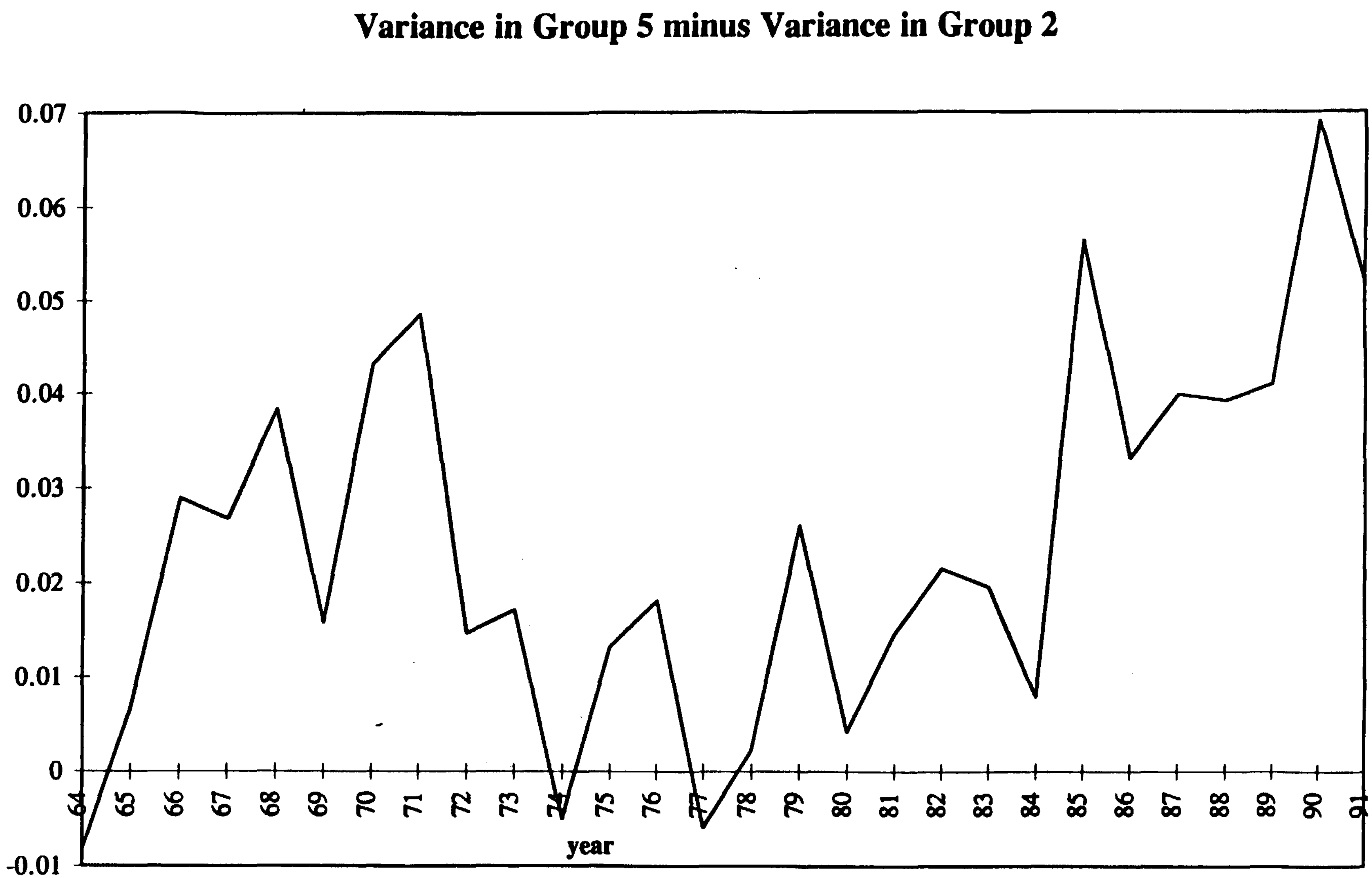

Covariance (r,s)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
Year
64
66
68
70
72
74
76
78
80
82
84
86
88
90

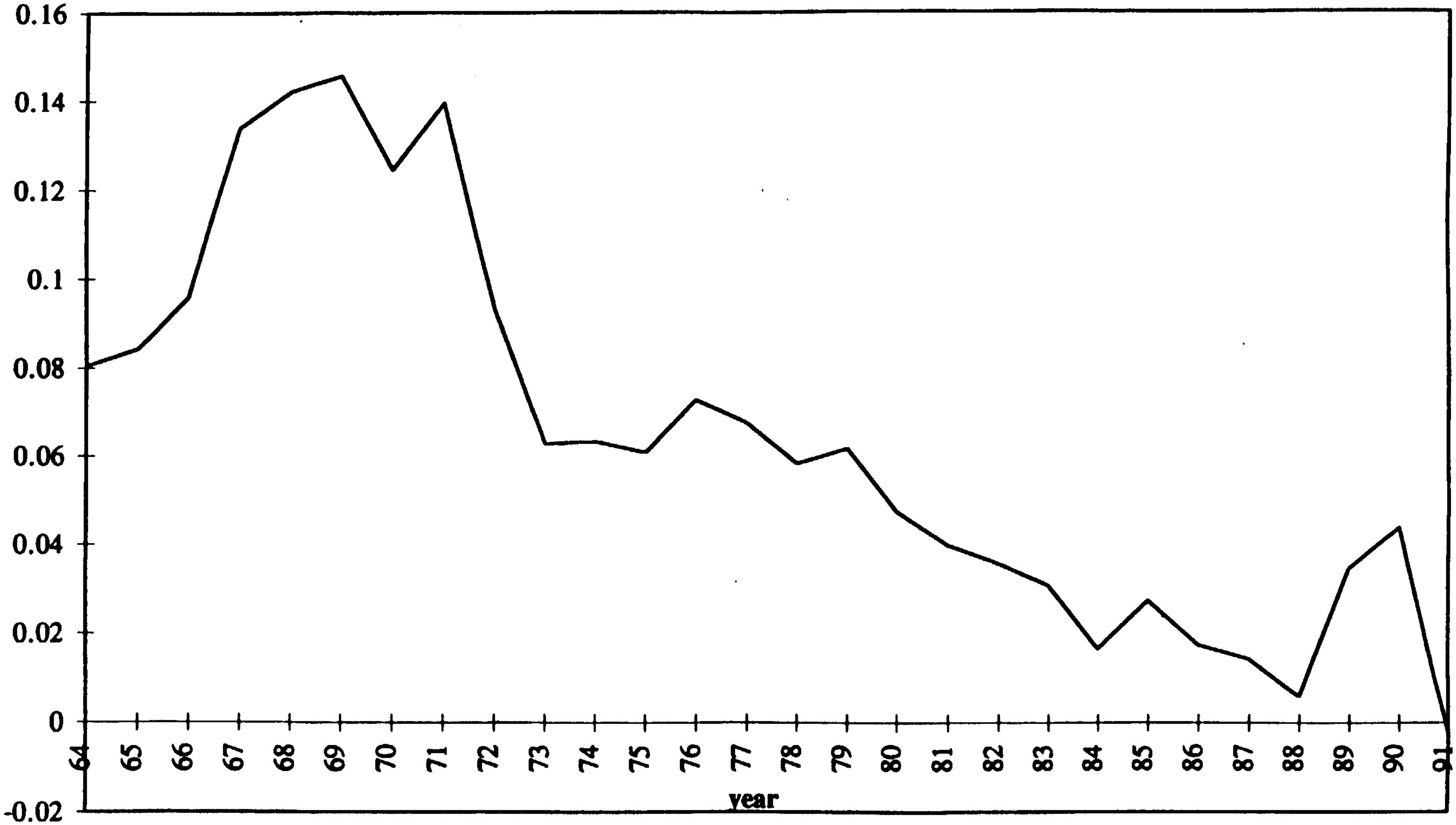
Figure 7



Group 5: 21 to 25 years of experience
Group 2: 6 to 10 years of experience

Figure 8

Variance in Group 1 minus Variance in Group 2



Group 1: 1 to 5 years of experience
Group 2: 6 to 10 years of experience