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THE EFFECT OF EARLY COGNITIVE ABILITY ON EARNINGS OVER THE LIFE-CYCLE

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The effect of early cognitive ability on earnings over the life-cycle*

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Abstract

This paper utilizes information on cognitive ability at age ten and earnings information from age 20 to 65 to estimate the return to ability over the life-cycle. Ability measured at an early age is not influenced by the individual's choices of schooling and other circumstances. We find that most of the unconditional return to early cognitive ability goes through educational choice. The conditional return is increasing for low levels of experience and non-increasing for experience above about 15-25 years. The return is similar for men and women, and highest for individuals with academic education. Only a small part of the return can be explained by higher probability to have a supervisory position.

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Key words: Cognitive ability; life-cycle; earnings; IQ

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1. Introduction

Wages are equal to workers' productivity only under the assumption of perfect information. There are many reasons to believe that imperfect and asymmetric information are important in many instances, violating the assumption to some degree. With searching costs, it is optimal for employers and workers to continue searching only when expected gains exceed the searching costs, yielding rents to be divided between firms and workers and wage lower than productivity. In firms with internal labor markets, employees should be concerned about the present value of career compensations, and underpayment followed by overpayment in expectation terms may promote work incentives and help solving some of the initial information problems of the firms. Likewise, with signaling behavior of workers the employers rely on observed behavior to infer on unobserved characteristics related to productivity. All these examples are based on the notion that ability is hard to observe, which implies that ability is not fully rewarded in the labor market at least in the short run.

The information problem is likely to be most severe for workers entering the labor market because they have no work history to shed light on their productivity. Over time, employers learn more about individual workers, which presumably reduce the information problems and brings wages closer to productivity. The seminal papers of Farber and Gibbons (1996) and Altonji and Pierret (2001) develop dynamic models of wages based on the idea that hard to observe variables influencing productivity, as for example ability, will be increasingly rewarded as the workers are able to demonstrate their productivity.

Empirical research on 'employer learning' is limited by availability of variables observable for researches but hard to observe for employers. Almost all the evidence is based on National Longitudinal Survey of Youth 1979 (NLSY79), which includes several measures of vocational aptitude, among them the Armed Forces Qualifying Test (AFQT). For example Cawley et al. (1999) find significant effects of ability on wages, though they interpret the effects to be modest.[1] In this paper we use a completely different data set to estimate the relationship between the return to ability and experience, and in contrast to the existing literature we are able to estimate the effect of ability over the whole working career.

[1] Griliches and Mason (1972) and Griliches (1976, 1977) focus on how inclusion or omission of ability variables in an empirical model affects the estimated return to education, and find evidence of an ability bias. They use an earlier version of NLSY, as well as a data-set on U.S. military veterans. Sandgren (2007) presents evidence on this topic based on the data used in the present paper.

NLSY79 consists of a sample of individuals aged 14-21 in 1979 who accomplished intelligence tests in 1980. Some of the individuals had finished their schooling at the time of the test while others had not, and the share of the individuals that had finished their schooling varies across the cohorts. This may be important for the interpretation of the empirical results of for example Altonji and Pierret (2001) if schooling has a causal effect on the test score. Winship and Korenman (1997) and Hansen et al. (2004) find that schooling has a strong effect on the AFQT test score, a finding that is in accordance with the view among psychologists that environmental factors influence intelligence, see for example Sternberg and Grigorenko (2001).[2] It may be the case that AFQT types of tests only give reasonable precise measures of ability relevant for the labor market when taken after completed schooling. When schooling improves on measured ability, the measurement error in ability tests compared to the ability relevant in the labor market is likely to increase in the amount of schooling undertaken after the test. The estimated effect of ability within cohort and year will in this case under standard assumptions be biased against zero to a larger degree for observations of low experience (much schooling) than for observations of high experience (little schooling), spuriously pointing in the direction of employer learning.

The results on tests taken after completed education are influenced by a host of individual choices and pure conditional effects of ability are likely to be overestimated. In this paper we propose a different strategy. We estimate the return to early cognitive ability measured in primary school. Ability measured before any schooling choices are made is presumably closely related to innate cognitive ability, which should be distinguished from cognitive ability acquired through non-compulsory schooling and other circumstances of individual choice.

Our data consist of all pupils in the third grade in 1938 in the city of Malmö, Sweden. The large majority of the third graders were 10 years of age. The data include several ability measures from the third grade, including an IQ test, teacher grading and teacher subjective evaluation, together with scores on a test similar to AFQT for men at age 20. We utilize information from all these measures in our analysis. Earnings data for the cohort is available up to the age of 65.

[2] For example Griliches and Mason (1972) and Griliches (1976) and Falch and Sandgren (2006) also find that schooling improve on intelligence by using other data sets.

Farber and Gibbons (1996), Altonji and Pierret (2001) and Lange (2007) use NLSY79 to investigate employer learning effects up to 10-16 years of experience, relying on variation both across time and cohorts to identify the interaction between ability and experience in the wage equation. They find evidence of employer learning, and the results in Altonji and Pierret (1998) indicate that employer learning is strongest for experience of about 3-6 years. Lange (2007) finds that the interaction between AFQT and experience is concave up to experience of 15 years. Recent studies have also investigated the hypothesis that employer learning is asymmetric in the sense that the employer knowledge of incumbent workers is better than for workers hired from other firms, see for example Pinkston (2006) and Schönberg (2007). The evidence on this issue is mixed,[3] which may indicate that employer learning is not the only explanation of the positive relationship between experience and the return to ability. For example, workers may learn more about their own productivity when their experience increase ('employee learning') and change their wage claims and career plans accordingly. Hause (1972) argues that experience and ability is complements in producing earnings because ability increases the capacity to acquire job-relevant skills and more-complex skills, and enables the workers to use these skills. Lillard (1977) finds the same wage dynamics as the more recent employer learning literature, but interpret the results within a life-cycle human capital theory with intertemporal choices of investment in earnings potential. The access to or benefits from on-the-job-training may depend on learning capacity. Obviously, it is hard to statistically discriminate between different mechanisms contributing to an observed relationship between experience and return to ability.

The paper is organized as follows. In the next section we lay out the empirical approach. The data are presented in section 3, and section 4 presents the estimation results. We present how the effect of ability depends on experience using both semi-parametric and parametric specifications, we distinguish between different groups of individuals according to education level and gender, and we use different measures of ability. Finally we investigate whether cognitive ability at age 10 has any effect on the probability of holding a supervisory position later in life. Section 5 concludes.

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[3] Schönberg (2007) presents evidence against asymmetric learning. She finds that workers who switch firms are not negatively selected as implied by asymmetric learning and the return to AFQT increases with experience but varies little with tenure. Pinkston (2006), on the other hand, finds a significant effect of the interaction between AFQT and employment spell length in addition to the significant interaction effect with experience and interprets the results as evidence for asymmetric learning.

2. Empirical approach

Our model is close to Altonji and Pierret (2001). We assume that the wage in period t is determined at the start of the period and that actual productivity is observed at the end of the period. The logarithm of productivity f_{it} of worker i at time t is written

$$f_{it} = \alpha + \beta S_i + \gamma Z_i + H(t_i) + \varphi X_{it} + \mu_{it} \quad (1)$$

where S_i is education, Z_i is unobserved cognitive ability, $H(t_i)$ is the experience profile of productivity, X_{it} is other potential explanatory variables, and μ_{it} is an iid productivity shock.

Since ability is correlated with education, firms and workers may in absence of knowledge of Z use obtained education to make predictions. Assume that the relationship between Z and S is $Z_i = \phi S_i + v_i$, where v is unobservable with mean zero and uncorrelated with S. Then

$$E(Z_i \mid S_i)_t = \phi S_i + E(v_i \mid Q_{it-1}) \quad (2)$$

where Q_{it-1} represents available information when the wage is determined. At the end of each period a noisy signal of future productivity, $q_{it} = f_{it} - E(f_{it}) = \gamma(v_i - E(v_i \mid Q_{it-1})) + \mu_{it}$, is observed. The vector $Q_{it} = \{q_{i1}, q_{i2}, ..., q_{it}\}$ summarizes the information in all signals. When q_{it} arrives, Q is updated by for example the Bayesian rule.

The logarithm of the wage can be written

$$w_{it} = E(f_{it}) + \eta_{it} = \alpha + (\beta + \gamma\phi) S_i + H(t_i) + \varphi X_{it} + \gamma E(v_i \mid Q_{it-1}) + \eta_{it} \quad (3)$$

$E(v_i)$ is not directly observed by outsiders but correlated with ability and $E(v_i)$ changes over time as more signals arrive and firms learn about true worker productivity.

Consider first the case where the wage is determined solely by competition among firms, the case for which η_{it} is unrelated to S, Z and H. Consider estimating the model

$$w_{it} = a_t + b_t S_i + c_t Z_i + H(t_i) + \varphi X_{it} + \varepsilon_{it} \quad (4)$$

How fast the effect of cognitive ability increases depends on the amount of noise in the productivity signals. But when new information permits a better estimate of ability, the coefficient c will be non-decreasing in experience and the coefficient b will be non-increasing in experience. These predictions rely on the assumption that the true effects on productivity are constant. However, the Scandinavian evidence indicates that the return to education increases in the first years of the working career; see for example and Hægeland et al. (1999)

and Sandgren (2007). The experience profile is steeper for highly educated workers than for low educated workers. Allowing the return to education to vary over time, and denoting the effect of education in a model excluding Z for b_t', the model implies that $\left(b_t' - b_t\right)$ is non-increasing in experience.

One may question whether η is uncorrelated with E(f). Historically, equality of wage distribution has been a vital trade union objective. In Sweden, there was a sharp decline in overall wage dispersion during the 1970s, which is typically related to increased union strength under a highly centralized wage bargaining regime, see for example Hibbs and Locking (1996), although Edin and Holmlund (1995) argue that a substantial part of the relative pay movements can be explained by demand and supply factors.[4] If the decline in the wage dispersion was caused by changes in demand and supply, the return to observable productivity factors such as schooling is expected to decline. Regarding cognitive ability, major changes in supply cannot be expected over time, but changes in demand may change the return to ability.

If unions with low wage dispersion as an objective have an impact on the wage determination, then $\mathrm{Cov}\left(E\left(v \mid Q_t\right), \varepsilon_t\right) < 0$. Such a correlation implies that by estimating (4), we are estimating how different variables influence wages and not productivity. In terms of productivity, the negative correlation implies that all marginal effects estimated will be biased downwards. A complication factor, however, is that the union influence may have changed over time. Then it may be difficult to interpret the interaction effect between ability and experience because the effect of ability at different experience levels is to some extent identified at different points in time.

To take this potential problem into account, we include in the empirical model interaction terms between experience and all other variables in the model, including time. Another approach is to replace earnings as the dependent variable with the rank in the wage distribution. A compression of the wage distribution implies that high wage workers earn less compared to low wage workers, but does at the outset not alter their position in the wage distribution. This approach is, however, not bias free. When the wage inequality is reduced,

[4] The standard deviation of hourly earnings in Sweden declined by about one third from the late 1960s to the early 1980s, and thereafter it increased by 15-20 percent until the start of the 1990s, see Edin and Holmlund (1995) and Hibbs and Locking (1996).

the difference in the wage between workers close in rank is reduced, and less noise than before will alter their rank. A related problem is that highly educated workers in the public sector contributed significantly to the overall decline in the wage distribution in Sweden in the 1970s, which pushed them towards a lower rank in the wage distribution. Nevertheless, the rank in the wage distribution should be less influenced by changes in the overall wage distribution than the wage level.

3. Data

We use the Malmö Longitudinal Data-set, possibly the longest longitudinal data-set existing.[5] The data include all children in third grade in the city of Malmö in 1938, originally 1,542 individuals. The data collected in 1938 includes information on family background as well as different ability measures. The earnings information comes from different registers collected about each fifth year from the age of 20 in 1948 until the age of 65 in 1993, which was the formal retirement age in Sweden. A host of other information, as education level and work experience, is collected in four different questionnaires distributed in 1964, 1971, 1984 and 1994. The response rates for the questionnaires have been high, around 75 % each year. Since educational information is collected from both the questionnaire in 1964 and school registers, there is only about 3.5 percent missing observations. In addition, the IQ test taken at military enrolment is matched onto the sample for men.

The cognitive ability measures include an IQ test for all third-graders in the spring 1938, when the normal-aged pupils were in their tenth year of living.[6] When the original information was collected in 1938, each child in third grade in any school within the county of Malmö was included. The county consisted of both urban and rural areas. The IQ measure is available for the whole original cohort of third graders, with the exception of seven girls.[7] The test was constructed, after thorough testing on third-graders the year before, by Siver Hallgren – the initiator of the Malmö Study. The test consisted of four parts: word opposites, sentence completion, perception of identical figures, and disarranged sentences. In addition, there is information on the grade point average and teacher ratings. The teachers were asked

[5] The data are described in more detail in Husén (1950) and Sandgren (2005).

[6] Since the sample is based on third graders, the students do not necessarily need to be born the same year. In the data, 86.0 and 88.3 percent of the boys and girls, respectively, are born in 1928, 12.2 and 9.7 percent is born earlier and 1.8 and 2.0 percent is born later. The large number of over-aged students is probably due to class repetition.

[7] These girls had average scores on the other ability measures.

to make two types of ratings of the students in their class. In the first rating they gave an objective measure of overall cognitive ability on a scale from one to five. In the second rating only relative cognitive ability within class was to be considered by identifying the 15 percent weakest and strongest students.

Mean values and correlation coefficients between the different measures of cognitive ability are presented in Table 1. The mean IQ score is slightly below 100, which Husèn (1950) explains by the fact that there were more over-aged than under-aged pupils in the cohort and the over-aged had a propensity to perform below average. The correlation coefficients are in the range 0.5 to 0.75, with the lowest coefficients for rating within class. To simplify the presentation of the empirical results we will mainly rely on one compound variable instead of the four different measures of cognitive ability. When undertaking a principal component analysis on standardized values, the different ability measures come out with very similar weights. Thus, we have simply calculated the mean of the individuals' available ability measures from third grade. Information for the standardized counterpart, denoted Early cognitive ability, is presented in Table 1. For each individual there is information from at least two of the original ability measures. Regarding the IQ test for men done at military enrolment at age 20, it is highly correlated with the early cognitive ability variables, indicating that the reliability of the variables is good.

We have data on annual earnings from 13 different years.[8] For the first years, 1948, 1953, 1958 and 1963, only the tax registers in the county of Malmö were searched for information on annual earnings, and data on earnings are missing for some of those who reported in the questionnaire in 1964 that they worked these years. From 1971 and onwards, we use earnings data collected by Statistics Sweden, and thus all individuals alive and with legal earnings in Sweden are included. For the years 1968 and 1971 we have earnings information from both sources, and they are almost identical.[9] The problem of having data on annual earnings

[8] Register data for earnings are collected for the years 1948, 1953, 1958, 1963, 1968, 1969, 1971, 1974, 1978, 1982, 1986, 1990, and 1993. From 1971 and onwards taxable benefits are included, such as unemployment benefits. Before 1971 these earnings were not taxable and thus not registered with the tax registers.

[9] For 1968 the Malmö data include more individuals than the data from Statistics Sweden, while the opposite is true for 1971. Thus, in the empirical analysis we use the Malmö data up to 1969 and data from Statistics Sweden from 1971. In the original Malmö study, earnings are reported in thousand SEK. In 1948 there are 13 earning levels in the data, while in 1969 there are 106 earning levels. From 1971 the precise earning is reported.

instead of hourly earnings is likely to be most pronounced for women because they work part-time to a much larger degree than men.[10]

The growth in earnings in the empirical period cannot be explained by the cognitive ability of the workers, but the variation in earnings is relevant for the interpretation of the empirical results. Figure 1 presents the standard deviation of log earnings. The standard deviation for men varies from 0.45 to 0.7, and is lowest in the 1950s and highest in 1968 and 1986. The standard deviation is larger for women, probably due to more part-time work and a varying labor supply over the time period. The general decline in the earnings dispersion in the 1970s in Sweden is hardly visible for this cohort, but a raising trend stops around 1970.

In the conditional model estimated below the return to ability is related to experience. However, actual experience may include information to the employers about worker quality and effort because it is an outcome variable itself. Thus, we will mainly rely on potential experience in this paper.[11] When constructing potential experience we take possible grade repetition up to grade three into account, but not thereafter. In particular one would expect grade repetition towards the end of compulsory schooling to convey information relevant for employers.[12] Notice that since we only have data for one cohort and no variation in years of education within individuals, potential experience and education is perfectly correlated; it is not possible to distinguish between the return to schooling and experience.

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[10] We do not have information on hours of work, hence not on potential part-time work. However, among the men in this cohort part-time jobs were rare. What might occur though is that some individuals did not work the whole year, for example because of shorter spells of unemployment or seasonal work. The unemployment in Sweden was extremely low up to the 1990s, at average about two percent. In the empirical analysis we include a dummy variable for earning clearly below full-time full-year wage, including 5.4 percent of the observations for men and 29.5 percent of the observations for women.

[11] We will also report results for models replacing potential experience with actual experience. Actual experience is calculated using occupational information given in the questionnaires, which implies that there are some missing observations. For the period up to 1951, we have assumed that the individual entered the labor market when finishing education if information from the questionnaire in 1964 is missing. For the period after 1951, we have assumed, if information is missing, that the individual is working if he worked the previous year. However, since we are forced to do a few assumptions here, and there is still missing values for 24 and 28 percent of the observations for men and women, respectively, we mainly rely on potential experience in the empirical model. In addition, those who have not answered the questionnaires have somewhat lower scores on the ability measures, less education and less earnings compared to those who returned the questionnaires, although the differences are quite small. The correlation coefficient between actual and potential experience is 0.95 for men, reflecting high employment probability among the men in the empirical period. For women, the correlation coefficient is 0.70.

[12] Potential experience is calculated using the formula “year - 1935 - years of schooling”. 1935 is the year the normal-aged enrolled school.

Figure 2 presents the number of observations for which there is information on earnings and potential experience. Because earnings data are only available each fifth year up to the age of 40, and some type of education is more common than others, the number of observations varies.

Because schools end in the spring, the first half year of working is not included in the analysis. The lowest possible potential experience is therefore one. Individuals with 12 years of education have potential experience of one in 1948, the first year with earnings information. In fact, no men in the sample undertook 12 years of education.[13] Thus, in the sample of men, the lowest observed potential experience is two years. About 45 percent of both men and women finished school after seven years of compulsory primary education, and they had six years of potential experience in 1948. For 1948 there are earnings observations for only 39 percent of the total sample, but at age 20 some individuals were still students while others undertook unpaid compulsory military service.[14] The relatively small number of observations with experience below ten years may make it hard to identify the effect of ability when experience is low. The number of observations for each experience level increases for experience levels above about 20 years since the earnings information was collected with smaller time intervals from 1968 and the scope of the data collection improved.

Table 2 presents descriptive statistics for the other variables used in the analysis, both for the original sample and for the sub-sample of individuals with all necessary information to be included. We classify education into different types. The Swedish school system was rather messy during this time period, and for example vocational school and lower secondary school involved a similar amount of years in school, but very different educations. There are pronounced differences between the genders, both regarding education and earnings. Lower secondary education was most common among women, and higher education was most common among men. Many of the women were housewives for long periods of time, which can also be seen through the variable actual experience, which is much lower than potential experience for the women.

[13] The educational types requiring 12 years of schooling led to typically female jobs, for example hospital nurses.
[14] The number of men and women, respectively, included in the analysis is 259 and 241 in 1948, 354 and 308 in 1953, 478 and 259 in 1958, and 649 and 320 in 1963.

One critical problem in identifying changes in the return to ability is to disentangle such possible changes from age and time effects, see Heckman and Vytlacil (2001). In this paper, the age effect is not a concern because we only consider one cohort, defined as those being in the third grade in 1938. To distinguish between time effects and changes in the return to ability, we specify a model with time specific effects and several interaction effects of experience, and estimate models both with earnings and rank in the wage distribution as dependent variable. The rank within the sample is calculated separately for gender and year. Because the number of observations varies across years, we use yearly standardized values in the analysis.

4. The return to cognitive ability over the life-cycle

We focus on the return to ability for men as in the existing literature, but in the last part of this section we include an analysis of women. We start out by presenting the unconditional return to early cognitive ability at different ages. Thereafter we estimate conditional models. We present results from different specifications of the relationship between experience and the return to ability, and we analyze whether the results are sensitive to the handling of experience, education, part-time work and individual characteristics, and whether the return differ between education types and ability measures.

4.1. Unconditional return to cognitive ability and education

Figure 3a presents the unconditional returns for men to one standard deviation in Early cognitive ability by estimating separate models for each year. In 1948 and 1953, at ages 20 and 25, the return to standardized ability was about six percent and about significant at five percent level. Thereafter the unconditional return increases to about 25 percent around 1970, and decline to below 20 percent in the 1980s.

Some of the return to ability described in Figure 3a is likely to go through educational choices. High ability individuals are more likely to undertake higher education than low ability individuals. But contrary to NLSY79, there are many individuals in the present data with high ability and only primary education (seven years of education). The correlation of cognitive ability and years of education is slightly above 0.5.[15] Figure 3b presents the return

[15] Heckman and Vytlacil (2001) make the point that if the relationship between education and ability becomes too strong, it is impossible to disentangle the effects of education and ability. They show that in NLSY79 only

to ability from a model formulation expanding the unconditional model with years of education allowing for year specific returns of both ability and education. The return to ability is similar to the unconditional return until 1953, but thereafter it grows more slowly and is reduced by more than 50 percent compared to the unconditional return.[16] A major effect of ability in economic terms seems to be on educational choices. Notice, however, that the variable years of education is each year perfectly correlated with potential experience. A smaller increase in the return to ability in the conditional model than in the unconditional model may in part be due to concave return to experience.

One hypothesis from the theoretical setup above is that the return to education is lower in a model that conditions on ability than in an unconditional model, and that the difference is non-decreasing over time. Figure 4 presents the return to education from the same model as in Figure 3. The return to education is each year lower in the model conditioning on ability than in the unconditional model, and there is a tendency of an increasing difference. The difference is about 0.5 percentage points up to 1953, about 1.2 percentage points in 1958-1970 and about 1.5 percentage points thereafter.

4.2. Conditional return to cognitive ability

We start by investigating the functional form of the interaction effect between ability and experience by a semi-parametric approach. We construct dummy variables for potential experience with two year intervals (one and two years of potential experience, three and fours years, and so on) and interact them with the variable Early cognitive ability. Figure 5 presents the coefficients of the interaction terms (in addition to two parametric models presented below). The model also allows for separate effects of the dummy variables and, in addition, includes dummy variables for educational type, never being married, working part-time, retiree, and year, and a cube in potential experience. All variables are interacted with potential experience to reduce the probability that the interaction effect of potential experience and ability is spurious.

1.0 percent with ability above median has less than 12 years of education and only 2.7 percent of the individuals in the lowest quartile in the ability distribution have above 14 years of education. Our data have the same feature for the individuals with lowest ability, but the individuals with highest ability is distributed across all types of schooling. The difference is probably related to lower education level in general within older cohorts.

[16] The return to early cognitive ability is lowest in 1986. It seems like the few observations of part-time work (five percent) have a specific impact in 1986. Excluding observations of part-time work, the return to ability is about the same in 1986 as in the surrounding years.

The return to one standard deviation in Early cognitive ability is estimated to below three percent in six out of seven estimates for potential experience below 15 years. In contrast, for potential experience from 15 to 36 years, all 11 estimates are above three percent and four of the estimates are above five percent. Thus, it seems like the return to cognitive ability increases after the first years of the working career. The return seems to be somewhat lower when potential experience exceeds 36 years.

Table 3 presents different models parameterizing the interaction between experience and cognitive ability. These models include the same controls as above except the dummy variables for potential experience. We start with a model linear in ability in column (1). On average over the life-cycle, the conditional return to one standard deviation in Early cognitive ability is slightly above four percent and highly significant.[17] The estimate is below the results in Altonji and Pierret (2001) and Schönberg (2007), which is based on tests taken later in life and include the effects of individual choices as for example non-compulsory education. In column (2) we add a linear interaction with potential experience, a model formulation similar to Altonji and Pierret (2001). The interaction term is positive, but clearly insignificant. This result is as expected; if employer learning is strongest early in the working life a linear interaction will not yield a good description of the life-cycle return to ability. In column (3) we follow Schönberg (2007) and include interaction with experience squared. As Schönberg we find that without any experience the return to ability is close to zero, but we find smaller coefficients of the interaction terms. The return to ability is maximized at about 35 years of experience, clearly higher than the result in Schönberg of about 20 years.

Multicollinearity seems to limit the possibility to estimate flexible functional forms. Even though the level effect of ability is very close to zero in the model in column (3), excluding the level effect (column (4)) increases the significance of the interaction terms markedly. The model in column (5) adds interaction with the third polynomial of potential experience, but the effect is insignificant.[18]

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[17] This estimate cannot directly be interpreted as the mean of a random individual because the attrition is lower in the start of the period. Thus, the mean individual return is expected to be lower. Using weighted regression with the inverse of the number of observations for each level of potential experience as weight, the average return is estimated to 4.0 percent.

[18] When ability at level is excluded from the model in column (5), only the effect of the linear interaction is significant at ten percent level.

Columns (6)-(9) in Table 3 present results from piece-wise linear regressions. We have investigated several different model formulations, but with more than one knot the estimates are imprecise. For models with one knot the mean root square is minimized for the knot at 17 years of potential experience. This model is reported in column (6) in Table 3 and indicates that the return to ability is close to zero without any experience, increasing up to experience level of 17, and constant thereafter. Only the interaction between ability and experience up to 17 years has a significant effect in the models.

Two different specifications in Table 3 seem to capture the main features of the data in a reasonably simplistic way; columns (4) and (9). In both models the effect of cognitive ability is equal to zero when finishing education, and it cannot be rejected at standard significance levels that the models are valid simplifications of the more general models allowing the effect of ability to differ from zero when finishing education. The models are illustrated in Figure 5 above. They are very similar and impossible to distinguish statistically.

The models presented so far does not include education directly because education and potential experience is perfectly correlated each year and the models include interaction terms between year and experience.[19] The interaction between education and experience can, however, be identified by excluding the interaction between year and experience from the model. That is done in the models in the last part of Table 3, which also exclude the dummy variables for education type. The model re-specification hardly changes the effect of ability. The interaction between education and experience is negative, which imply that the increasing return to education reported in Figure 4 is not due to increased experience but other time specific factors. Further, the interaction effect is not sensitive to the handling of ability. This indicates that the schooling and ability coefficients over the life-cycle are not driven by the same learning process, in contrast to the findings from the NLSY. In the following we use the initial and more flexible model formulation.

The seemingly decline in the return to ability in the last years of the working life in Figure 5may come about by the overall compression of the wage distribution that took place in Sweden in particular in the 1970s. In Figure 6 and Table 4 we use the rank in the wage

[19] The studies using NLSY identifies the effect of education on individuals undertaking education after they have started their working career. That is not possible in the present data because information on education is based on a survey at age 37.

distribution as the dependent variable to shed some light on whether the general wage compression affects the estimation results. The semi-parametric model in Figure 6 indicates that early in the working life, the return to ability in terms of rank is more volatile than the return in earnings. Most interesting, the return seems to decline after potential experience of about 35 years. Individuals with only primary education had potential experience of 35 in 1978, towards the end of the period with wage compression in Sweden. The low return for potential experience of 43-46 years can thus not be explained by union influence in the 1970s.

The high return to ability for potential experience above 46 implies that the rank model is not well parameterized by an interaction between ability and experience squared as shown in Table 4.[20] The model including interaction with the cube of potential experience fits the data reasonable well and is presented in Figure 6 together with the spline specification for which the results are very close to the earnings model.[21] Overall, the results do not support that the compression in the income distribution in the 1970s affects the estimated return to ability over the life-cycle.

4.2. The handling of experience and other individual characteristics

If employer learning is important, the return to education should be expected to depend on actual experience and not potential experience. Column (1) in Table 5 present results for different model specifications in which potential experience is replaced with actual experience. Since the correlation coefficient between the experience variables is very high, the results are as expected qualitatively similar to the models above. The main difference is that the return to ability seems to be more hump-shaped over the life-cycle, with the maximum return at 24 years, somewhat lower than in the model with potential experience.

The model in Column (1) in Table 5 is identical to the models in Table 3 except the definition of experience. But since potential experience is not included, neither is education since education and potential experience is perfectly correlated. Education is included in column (2) (and is also interacted with actual experience as all variables), without altering the results.

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[20] If the model is estimated including only observations of potential experience up to 45 years, the results is very similar o the model with log earnings as dependent variable. The level effect is close to zero, and the return to ability is highest for about 26 years of potential experience.

[21] Notice however, that since the standard deviation of the rank in the income distribution is about twice as large as the standard deviation of log earnings, the coefficients are not directly comparable.

The last two columns of Table 5 show that the results are fairly robust with regard to the model specification of potential experience. In column (3), potential experience is replaced by dummy variables for years of education. Because the model includes interaction terms, the number of 'control' variables increases to 171 in this specification. The average return to ability increases slightly to 4.5 percent, but the next three regressions in column (3) show that the return to ability over the life-cycle is similar to the models reported in Table 3. Column (4) shows that the same is true for a parsimonious model without any interaction effects except between potential experience and ability.

Table 6 investigates the robustness of the results with regard to some other variables. Column (1) shows that the results are not sensitive to whether the dummy variables for marital status and retirement are excluded from the model. Column (2) shows that the average return to ability increases when the dummy variable for working part-time is excluded. When considering working time to be a choice variable, the average return to cognitive ability increases to 6.2 percent. The results in the second and fourth regressions in column (2) indicate that the estimated return to ability over the life-cycle is sensitive to whether working part-time is included in the model or not. A closer look at the data reveals that, when the variable for working part-time is excluded, the return to ability above 45 years of experience develops more as the return to rank in Figure 5 than the return to earnings in Figure 4.[22] In Column (3) we exclude observations where the individuals work part-time. For this reduced sample, the estimated return to ability over the life-cycle is similar to the baseline models in Table 3.

Finally, there may in general be several additional differences between individuals that we do not include in the models. In particular, when estimating the effect of Early cognitive ability one would like to keep constant other aspects of the early childhood of the individuals, as for example family background and living conditions. The last column in Table 6 estimates fixed effect models. Notice that this model is over-parameterized in the sense that average characteristics over the working life of the individuals are also differenced out of the model, not only characteristics of the childhood. Thus, it is not possible to estimate the average return

[22] If observations with potential experience above 44 years are excluded from the sample, both interaction terms in the second regression in column (2) in Table 6 are significant at ten percent level, and the coefficients are about twice as large as in the model including the dummy variable for part-time work.

to ability in this case. But varying return to ability is possible to estimate, and in both the quadratic interaction specification and the spline specification, the return to ability over the life-cycle is almost identical to the estimates in the comparable models without fixed effects, although the precision of the estimates are lower.

4.3. Heterogeneity across education and ability measures

Unobserved ability is likely to be of different importance in different types of jobs. In the first part of this section we focus on differences between educational types, and in the second part we estimate models using the individual measures of ability instead of the compound measure used above. We also present results using our measure corresponding to the US AFQT test which should facilitate comparison with the US studies.

Table 7 presents results for two educational groups. We distinguish between no more than vocational education, including primary education, and others who have at least lower secondary school.[23] There are clear differences in the return to ability between the two groups. The conditional average return to ability is more than twice as large for individuals with academic education than for vocational education. In addition, it seems like the vocationally educated need more time in the labor market until the return to ability is maximized. In fact, the effect of the interaction with experience squared is clearly insignificant, reflecting that we cannot reject that the return to ability is increasing over the whole life-cycle.

On the other hand, the return to ability for individuals with academically educated seems to decline markedly against the retirement age. The peak of the return for the specifications in columns (2) and (3) is at 26 years of potential experience. Notice, however, that we are not able to statistically discriminate between the model specification in columns (3) and the spline specification in column (5).

Our measure of cognitive ability is a compound variable based on four different ability measures at age 10. It is interesting to investigate the effect of the different measures of ability separately. Is it the IQ score that is important, or is it the performance in school? In Table 8 we present models using only one of the ability measures at time.

[23] Average Early cognitive ability differs between the groups. Average ability is -0.31 (0.97) for individuals with vocational education and 0.80 (0.81) for academic education, standard deviations in parentheses.

The return to teacher rating within class is smaller than teacher overall rating because of lower return late in life. The return to GPA in third grade is on average slightly smaller than the return to our compound variable, but otherwise very similar over the life-cycle. Out of the individual ability measures in third grade, the return is highest for the IQ score. However, the return to IQ seems to increase late in life, which implies that the model specification with interaction between ability and squared experience does not describe the data very well.[24]

Lastly, Column (5) in Table 8 presents the results when using the IQ score at military enrollment as the measure of ability. The effect of the IQ measured at age 20 is clearly higher than ability measured ten years earlier. The average effect is larger than reported by Schönberg (2007) but smaller than reported by Altonji and Pierret (2001). While Schönberg only includes white men in the sample, Altonji and Pierret additionally include blacks and women, and the different returns estimated in these studies seems to be a result of the difference in sample. Thus, Schönberg (2007) is more comparable with the present study than Altonji and Pierret (2001).

Educational choice is likely to be one reason why the conditional return to IQ measured at age 20 is higher than IQ measured at age 10. Falch and Sandgren (2006) find that education has a major effect on IQ at age 20, and thus the return to IQ at age 20 will in part capture the return to education. In unconditional models, we find that the average return to IQ at age 10 and 20 is 0.19 and 0.20, respectively, the same as the return to our compound ability measure. Regarding the return to IQ at age 20 over the life-cycle, the pattern is similar to ability measured at age 10.

4.4. Return to cognitive ability for women

Since working careers and the level of earnings differ between the genders, we study the effect of ability separately for women. For the cohort in our sample women had less education, were home with children longer, and were house-wives to a larger degree than is common today.

[24] If observations with potential experience above 44 years are excluded from the model, the results of all model specifications where ability is measured by IQ in third grade are very close to the results for the models with the compound ability measure in Table 3, including the average return.

Figure 7 presents the unconditional return to cognitive ability for women. Figure 7a shows that the return to cognitive ability is about 15 percent each year, but varies somewhat in the first three years of the sample period. The return over the life-cycle differ markedly from the case of men reported in Figure 2a, and it is hard to interpret the results as being in accordance with the hypothesis of employer learning. The difference between men and women may be a result of the fact that the figures are conditional on labor market participation or that the decision of part-time work differs across the genders. We can approach the latter. In Figure 7b, observations with part-time work is excluded, which give a picture more similar to that for men, although the return is lower.

Figure 8 and Table 9 present results for conditional models. Compared to men, Figure 8 shows that the return to ability is low for high and low experience levels. However, column (1) in Table 9 shows that the average conditional return is slightly higher for women than for men. It follows from Figure 8 that a functional form with interaction between ability and squared potential experience gives a reasonable fit to the data, and both interaction terms in columns (2) and (4) in Table 9 is highly significant. Cawley et al. (1999) conclude that the return to ability differ between both gender and race, but a close look at their results reveals that the difference between white males and females, which is the relevant comparison in our case, is rather small. Thus, their results seem in this respect to be similar to ours.

The correlation coefficient between actual and potential experience is 0.70 for women, clearly lower than for men. Table 10 shows that by simply replacing potential experience with actual experience in the model for women, the estimated coefficients do, however, not change much. The largest change is that the quadratic interaction term becomes insignificant. In the last part of Table 10, we distinguish between individuals with vocational and academic education. As for men, we find that the return to ability is highest within the group of academically educated. The average return to ability for individuals with vocational training is insignificant, although there seems to be a hump-shaped return over the life-cycle as for the whole sample. Regarding the sample with academic education, the return to ability is large and highly non-linear.

4.5. Cognitive ability and supervisory positions

Demonstrated competence and productivity is often a premise for promotion to more influential positions. The return to ability may increase in experience because promotions to leader positions are more likely among high-ability individuals. From the questionnaires in 1964, 1971 and 1984 we have information on whether the individuals have supervisory positions. The information is available for 92 percent of the individuals included in the earnings equations. A rising share of the sample has a supervisory position, increasing from 28 percent in 1964 to 32 percent in 1971 and 39 percent in 1984.

We investigate whether Early cognitive ability influence the probability to have a supervisory position by estimating linear probability models with the same specification as the earnings equations. Table 11 presents the results. One standard deviation in Early cognitive ability increases the probability to have a supervisory position by 3.2 percent for men, which is significant at 10 percent level. The effect seems to be larger for academically educated than for vocationally educated, but is not statistically significant for neither of the groups. The results for women are similar to the results for men.[25]

Can the return to ability in terms of earnings be explained by promotions to supervisory positions? To investigate this question we firstly run the conditional earnings model on the sample with information on supervisory position, and secondly add the dummy variable for supervisory position. The difference in return to ability between these two models turns out to be rather small; the estimate decreases from 0.027 to 0.021 for men and from 0.040 to 0.033 for women. Thus, promotions to supervisory positions only explain a small part of the return to cognitive ability, although the return to supervisory positions is 0.17 and 0.26 log points for men and women, respectively.

5. Conclusion

We estimate the return to ability at age 10 on earnings at age 20-65 and find that the conditional return increases the first 15-25 years after finishing school. Increasing returns to ability may be a result of 'employer learning', but may also be explained by 'employee learning' or that experience and ability are complements in producing productivity gains and earnings. We find that the return to early cognitive ability over the life-cycle is similar for men and women, and highest for individuals with academic education. Early cognitive ability

[25] We have also investigated the effects of the separate ability measures on the probability of having a supervisory position. Only the IQ-measures have a significant effect at 10 percent level. For men we find an effect of 3.5 and 9.0 for IQ measured in third grade and at age 20, respectively, while for women the effect of IQ in third grade is 2.4.

seems to have a positive impact on the probability of being employed in a leader position, but only a small part of the return on earnings can be explained by this higher probability.

Previous studies have used ability measured after some schooling choices are made to investigate the return to ability on earnings, and the individuals are typically not tested at the same age. When schooling choices affect ability measures, the return to ability reflects both 'innate' ability and the choices made by the individuals, and when the individuals are tested at different ages the interaction between these factors may play a role. We find that the return to cognitive ability measured at age ten is smaller than the typical return to ability found in the literature. Increasing early cognitive ability by one standard deviation is estimated to increase earnings by about 4 percent on average over the life-cycle, conditional on inter alia education and experience. Given that the unconditional effect is about 20 percent, most of the effect of early cognitive ability seems to go trough educational choice. Thus, the return to ability in previous studies may be overestimated in the sense that they partly include the return to education.

On the other hand, we find that the return to ability measured at age 20 is larger than the return to ability found in the previous literature. If schooling improves on measured ability, the case where individuals are tested at different ages and with different years of schooling introduces correlations between measurement error in ability and age at test, schooling, and labor market experience. This is likely to induce a negative bias in the return to ability, in particular at low experience levels under standard identifying conditions.

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Table 1. The measures of ability, men and women.

	Obser-vations	Mean	Standard deviation	Correlation coefficients				
				IQ 10	GPA3	Rating O	Rating W	Ability
IQ in third grade (IQ 10)	1,535	98.1	16.37					
Grade point average third grade (GPA3)	1,486	3.5	0.56	0.660				
Teacher overall rating (Rating O)	1,416	2.92	1.23	0.660	0.730			
Teacher rating within class (Rating W)	1,416	2.01	0.53	0.492	0.566	0.656		
Early cognitive ability (Ability)	1,542	0	1.00	0.833	0.867	0.900	0.800	
IQ at age 20	653	97.6	16.47	0.751	0.607	0.615	0.423	0.731

Note. Calculated on the original sample in 1938.

Table 2. Descriptive statistics, standard deviation in parentheses

	Men		Women	
	Original sample	Sub-ample	Original sample	Sub-sample
Primary school, 7 years of education	0.47	0.45	0.48	0.47
Vocational school, about 9 years of education	0.27	0.27	0.25	0.25
Lower secondary school, about 9 years of education	0.12	0.13	0.18	0.18
Upper sec. school and above, at least 12 years of education	0.15	0.15	0.09	0.10
Years of education	8.1 (3.3)	8.9 (2.6)	7.7 (3.2)	8.7 (2.1)
Actual experience in years, 1993	45.2 (2.5)	44.8 (6.7)	33.9 (12.6)	33.5 (12.4)
Potential experience in years, 1993	49.1 (2.5)	48.9 (2.7)	49.3 (2.0)	49.3 (2.1)
Marital status – have never been married	0.09	0.09	0.06	0.04
Working part-time	-	0.07	-	0.35
Observations	834	726	708	602

Table 3. The effect of cognitive ability over the life-cycle. Dependent variable is log yearly earnings for men

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Early cognitive ability	0.042**	0.029~	-0.002	-	-0.040	-0.022	-0.020	-	-	0.047**	-	-
	(0.011)	(0.016)	(0.025)		(0.039)	(0.029)	(0.029)			(0.012)		
Interaction between Early cognitive ability and												
Potential experience / 100	-	0.044	0.300	0.288**	0.904~	-	-	-	-	-	0.295**	-
		(0.054)	(0.185)	(0.088)	(0.518)						(0.089)	
Potential experience squared / 100	-	-	-0.0044	-0.0042*	-0.0293	-	-	-	-	-	-0.0040*	-
			(0.0029)	(0.0019)	(0.0204)						(0.0019)	
Potential experience cube / 1,000	-	-	-	-	0.0030	-	-	-	-	-	-	-
					(0.0024)							
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	-	-	0.416*	0.386~	0.277**	0.268**	-	-	0.301**
						(0.204)	(0.199)	(0.080)	(0.072)			(0.072)
Potential experience / 100. Constant to 17, linear thereafter	-	-	-	-	-	-0.019	-	-0.010	-	-	-	-
						(0.064)		(0.064)				
Interaction between potential experience / 100 and												
Education	-	-	-	-	-	-	-	-	-	-0.0082*	-0.0083*	-0.0083*
										(0.0033)	(0.0033)	(0.0033)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Dummy variables for educational type	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
R^2	0.5574	0.5575	0.5576	0.5576	0.5577	0.5576	0.5576	0.5576	0.5576	0.5529	0.5531	0.5533

Note. 7,669 observations. In addition to the reported variables, the models include: a cubic of potential experience, three dummy variables for educational type, marital status, year specific effects, a imputed dummy variable for part-time work, and a dummy for early retirement. All variables are interacted with potential experience. To calculate a meaningful R^2 the mean log wage is set equal to zero each year. ~, * and ** denote significance at ten, five and one percent level, respectively. Standard errors in parentheses, corrected to account for within-individual clustering of errors.

Table 4. The effect of cognitive ability over the life-cycle. Dependent variable is standardized value of yearly rank of earnings within sample for men

	(1)	(2)	(3)	(4)	(5)	(6)
Early cognitive ability	0.080** (0.021)	0.050 (0.063)	-0.063 (0.090)	-	0.001 (0.074)	-
Interaction between Early cognitive ability and						
Potential experience / 100	-	0.147 (0.419)	1.942~ (1.103)	1.181* (0.478)	-	-
Potential experience squared / 100	-	-0.0013 (0.0066)	-0.0754~ (0.0410)	-0.0487~ (0.0252)	-	-
Potential experience cube / 1,000	-	-	0.0088~ (0.0046)	0.0059~ (0.0033)	-	-
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	-	0.500 (0.467)	0.500** (0.128)
R^2	0.5168	0.5169	0.5171	0.5171	0.5169	0.5169

Note. See Table 3. Same model specification as in Table 3 except as indicated.

Table 5. Different handling of experience. Dependent variable is log yearly earnings for men

	(1)	(2)	(3)	(4)
Specification change compared to Table 3	Replacing potential experience with actual experience	As column (1), but in addition including years of education	Replacing potential experience with dummy variables for years of education	Excluding all interactions with potential experience
Early cognitive ability	0.038**	0.033*	0.045**	0.042**
	(0.014)	(0.014)	(0.012)	(0.012)
R^2	0.5038	0.5147	0.5778	0.5417
Early cognitive ability	0.013	0.013	-0.016	0.001
	(0.036)	(0.036)	(0.029)	(0.029)
Interaction between Early cognitive ability and				
Experience / 100	0.329	0.279	0.409~	0.220
	(0.273)	(0.274)	(0.214)	(0.203)
Experience squared / 100	-0.0073	-0.0063	-0.0059~	-0.0024
	(0.0048)	(0.0048)	(0.0034)	(0.0032)
R^2	0.5043	0.5150	0.5781	0.5419
Interaction between Early cognitive ability and				
Experience / 100	0.419**	0.370**	0.301**	0.230*
	(0.128)	(0.119)	(0.088)	(0.090)
Experience squared / 100	-0.0087**	-0.0077**	-0.0043*	-0.0026
	(0.0030)	(0.0028)	(0.0019)	(0.0019)
R^2	0.5042	0.5150	0.5781	0.5419
Early cognitive ability	0.014	0.003	-0.038	-0.055
	(0.030)	(0.031)	(0.0037)	(0.034)
Interaction between Early cognitive ability and Experience up to 17 / 100 (spline)	0.126	0.163	0.515*	0.601**
	(0.176)	(0.180)	(0.242)	(0.219)
R^2	0.5039	0.5147	0.5782	0.5423
Interaction between Early cognitive ability and Experience up to 17 / 100 (spline)	0.200**	0.178*	0.287**	0.272**
	(0.077)	(0.073)	(0.074)	(0.074)
R^2	0.5038	0.5147	0.5781	0.5421
Observations	5,855	5,855	7,669	7,669

Note. See Table 3. Same model specification as in Table 3 except as indicated.

Table 6. Different handling of individual characteristics. Dependent variable is log yearly earnings for men

	(1)	(2)	(3)	(4)
Specification change compared to Table 3	Excluding dummy variables for marital status and retirement	Excluding the dummy variable for part-time work	Excluding observations of part-time work	Individual fixed effects
Early cognitive ability	0.043**	0.062**	0.050**	-
	(0.012)	(0.015)	(0.011)	
R^2	0.5477	0.2600	0.3728	-
Early cognitive ability	-0.007	0.055~	0.007	-
	(0.025)	(0.033)	(0.026)	
Interaction between Early cognitive ability and				
Potential experience / 100	0.363~	0.047	0.217	-
	(0.186)	(0.250)	(0.190)	
Potential experience squared / 100	-0.0056~	-0.0007	-0.0022	-
	(0.0029)	(0.0039)	(0.0030)	
R^2	0.5479	0.2600	0.3732	-
Interaction between Early cognitive ability and				
Potential experience / 100	0.313**	0.419**	0.266**	0.301
	(0.090)	(0.107)	(0.086)	(0.201)
Potential experience squared / 100	-0.0048*	-0.0063**	-0.0029	-0.0047
	(0.0019)	(0.0023)	(0.0018)	(0.0031)
R^2	0.5479	0.2598	0.3732	0.7675
Early cognitive ability	-0.018	0.029	-0.020	-
	(0.0029)	(0.039)	(0.031)	
Interaction between Early cognitive ability and Potential experience up to 17 / 100 (spline)	0.383~	0.206	0.431*	-
	(0.199)	(0.265)	(0.209)	
R^2	0.5479	0.2601	0.3732	-
Interaction between Early cognitive ability and Potential experience up to 17 / 100 (spline)	0.274**	0.381**	0.310**	0.384~
	(0.074)	(0.092)	(0.070)	(0.227)
R^2	0.5479	0.2600	0.3732	0.7675
Observations	7,669	7,669	7,258	7,669

Note. See Table 3. Same model specification as in Table 3 except as indicated.

Table 7. Vocationally and academically educated. The dependent variable is log yearly earnings for men

	(1)	(2)	(3)	(4)	(5)
A. Vocational education					
Early cognitive ability	0.030* (0.012)	-0.011 (0.026)	-	-0.020 (0.032)	-
Interaction between Early cognitive ability and					
Potential experience / 100	-	0.222 (0.192)	0.152~ (0.086)	-	-
Potential experience squared / 100	-	-0.0026 (0.0030)	-0.0015 (0.0018)	-	-
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	0.309 (0.224)	0.188** (0.073)
R^2	0.5203	0.5206	0.5205	0.5205	0.5205
Observations	5602	5602	5602	5602	5602
B. Academic education					
Cognitive ability	0.069* (0.029)	-0.004 (0.054)	-	0.015 (0.062)	-
Interaction between Early cognitive ability and					
Potential experience / 100	-	0.695 (0.464)	0.668** (0.219)	-	-
Potential experience squared / 100	-	-0.0133 (0.0082)	-0.0129* (0.0051)	-	-
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	0.340 (0.456)	0.434* (0.185)
R^2	0.4658	0.4665	0.4665	0.4660	0.4660
Observations	2,067	2,067	2,067	2,067	2,067

Note. See Table 3. Same model specification as in Table 3 except as indicated.

Table 8. The return to the individual ability measures. The dependent variable is log yearly earnings for men

	Teacher rating within class	Teacher overall rating	GPA third grade	IQ third grade	IQ at age 20
Cognitive ability	0.019~	0.031**	0.032**	0.049**	0.074**
	(0.010)	(0.011)	(0.011)	(0.011)	(0.013)
R^2	0.5610	0.5621	0.5541	0.5586	0.5291
Cognitive ability	-0.001	-0.008	0.012	0.017	0.005
	(0.025)	(0.027)	(0.021)	(0.027)	(0.032)
Interaction between Cognitive ability and					
Potential experience/100	0.200	0.228	0.157	0.136	0.405~
	(0.187)	(0.192)	(0.167)	(0.200)	(0.209)
Potential experience squared/100	-0.0038	-0.0029	-0.0026	-0.0009	-0.0051
	(0.0030)	(0.0030)	(0.0027)	(0.0031)	(0.0033)
R^2	0.5611	0.5623	0.5541	0.5588	0.5296
Interaction between Cognitive ability and					
Potential experience / 100	0.191*	0.177*	0.238**	0.250**	0.441**
	(.083)	(0.084)	(.084)	(.092)	(.121)
Potential experience squared / 100	-.0036*	-0.0021	-.0038*	-.0026	-.0056*
	(.0018)	(0.0018)	(.0018)	(.0019)	(.0026)
R^2	0.5611	0.5623	0.5541	0.5588	0.5295
Early cognitive ability	-0.017	-0.026	0.009	-0.003	-0.025
	(0.030)	(0.032)	(0.025)	(0.032)	(0.036)
Interaction between Early cognitive ability and Potential experience up to 17 / 100 (spline)	0.225	0.352~	0.143	0.321	0.621**
	(0.200)	(0.209)	(0.182)	(0.216)	(0.225)
R^2	0.5610	0.5624	0.5541	0.5588	0.5297
Interaction between Early cognitive ability and Potential experience up to 17 / 100 (spline)	0.124*	0.197**	0.200**	0.305**	0.467**
	(0.063)	(0.069)	(0.072)	(0.071)	(0.079)
R^2	0.5610	0.5623	0.5541	0.5588	0.5297
Observations	7,055	7,055	7,509	7,669	6,422

Note. See Table 3. Same model specification as in Table 3 except as indicated.

Table 9. The effect of cognitive ability over the life-cycle. Dependent variable is log yearly earnings of women

	(1)	(2)	(3)	(4)	(5)	(6)
Cognitive ability	0.051** (0.014)	-0.064~ (0.033)	-0.142** (0.054)	-	-0.084* (0.035)	-
Interaction between Early cognitive ability and						
Potential experience / 100	-	0.990** (0.295)	2.319** (0.851)	0.575** (0.149)	-	-
Potential experience squared / 100	-	-0.0171** (0.0051)	-0.0726* (0.0344)	-0.0110** (0.0034)	-	-
Potential experience cube / 1,000	-	-	0.0065 (0.0040)	-	-	-
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	-	0.547** (0.251)	0.339** (0.091)
R^2	0.5714	0.5723	0.5725	0.5721	0.5720	0.5718

Note. See Table 3. Same model specification as in Table 3 except as indicated. 5,586 observations.

Table 10. Actual vs. potential experience and vocationally vs. academically educated. The dependent variable is log yearly earnings for women

	(1)	(2)	(3)	(4)	(5)
A. Replacing potential with actual experience					
Early cognitive ability	0.049** (0.017)	-0.006 (0.051)	-	-0.087* (0.037)	-
Interaction between Early cognitive ability and					
Actual experience / 100	-	0.402 (0.442)	0.447* (0.219)	-	-
Actual experience squared / 100	-	-0.0073 (0.0088)	-0.0080 (0.0060)	-	-
Actual experience / 100. Linear to 17, constant thereafter	-	-	-	0.742** (0.223)	0.295** (0.094)
R^2	0.5858	0.5860	0.5860	0.5869	0.5865
Observations	4,036	4,036	4,036	4,036	4,036
A. Vocational education					
Early cognitive ability	0.024 (0.016)	-0.042 (0.040)	-	-0.045 (0.043)	-
Interaction between Early cognitive ability and					
Potential experience / 100	-	0.630~ (0.343)	0.360* (0.158)	-	-
Potential experience squared / 100	-	-0.0115* (0.0058)	-0.0075* (0.0035)	-	-
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	0.429 (0.306)	0.159 (0.104)
R^2	0.5513	0.5518	0.5517	0.5514	0.5514
Observations	4,058	4,058	4,058	4,058	4,058
B. Academic education					
Cognitive ability	0.106** (0.030)	-0.186** (0.064)	-	-0.189** (0.062)	-
Interaction between Early cognitive ability and					
Potential experience / 100	-	2.323** (0.611)	1.013** (0.332)	-	-
Potential experience squared / 100	-	-0.0388** (0.0117)	-0.0182* (0.0080)	-	-
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	1.865** (0.457)	0.721** (0.194)
R^2	0.6139	0.6175	0.6162	0.6170	0.6158
Observations	1,528	1,528	1,528	1,528	1,528

Note. See Table 3. Same model specification as in Table 3 except as indicated.

Table 11. Ability and leader position. Dependent variable is whether the individual has been a supervisor in 1964, 1971 or 1984

	Men	Vocational education, men	Academic education, men	Women
Early cognitive ability	0.032~	0.019	0.042	0.026
	(0.018)	(0.022)	(0.033)	(0.016)
R^2	0.1208	0.0694	0.0899	0.0826
Observations	1,562	1,060	502	945

Note. In addition to Early cognitive ability, the models include: a cubic of potential experience, three dummy variables for educational type, marital status, year specific effects, a imputed dummy variable for part-time work, and a dummy for early retirement. All variables are interacted with potential experience. ~ denotes significance at ten percent level. Standard errors in parentheses, corrected to account for within-individual clustering of errors.

Figure 1. Standard deviations of log yearly earnings

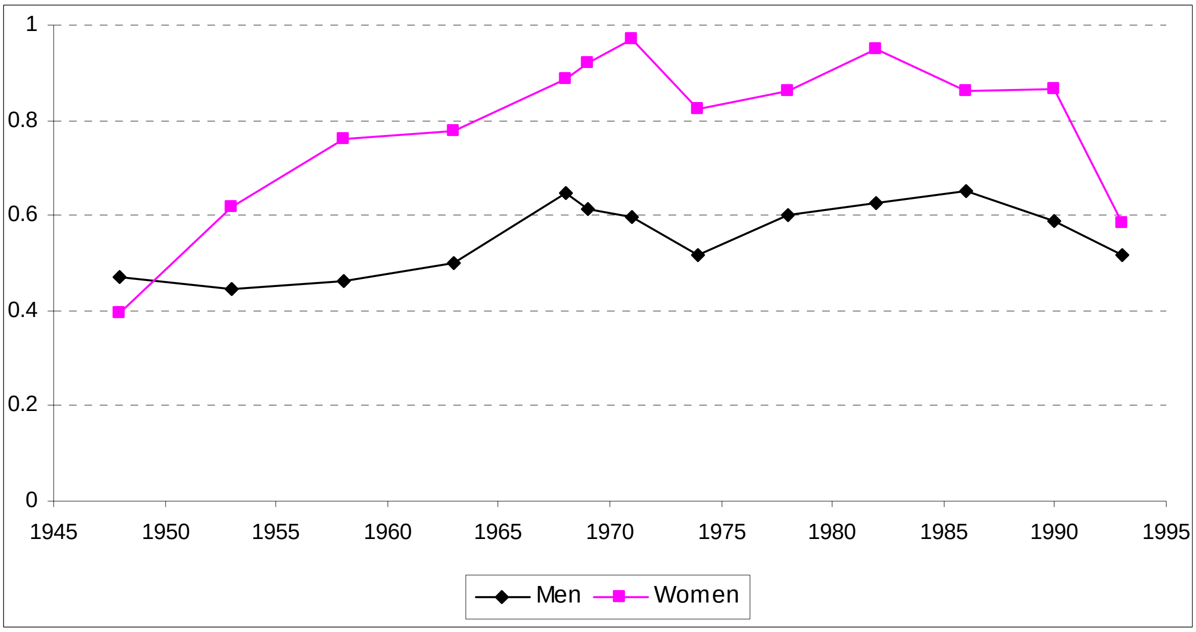


Figure 2. The number of observations for each level of potential experience

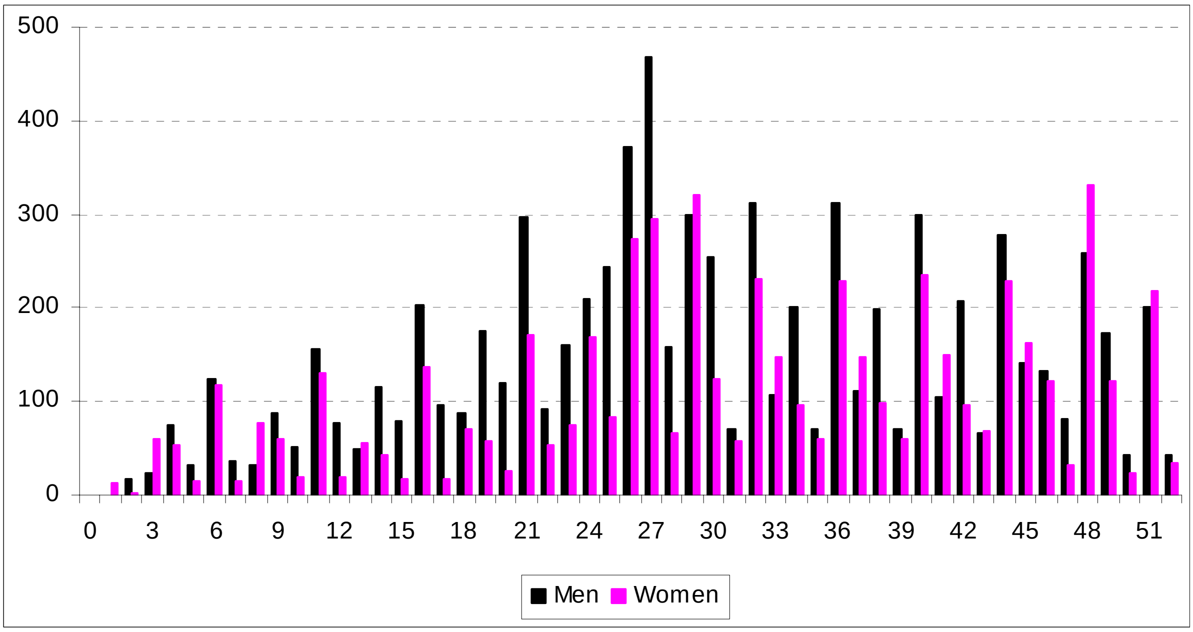
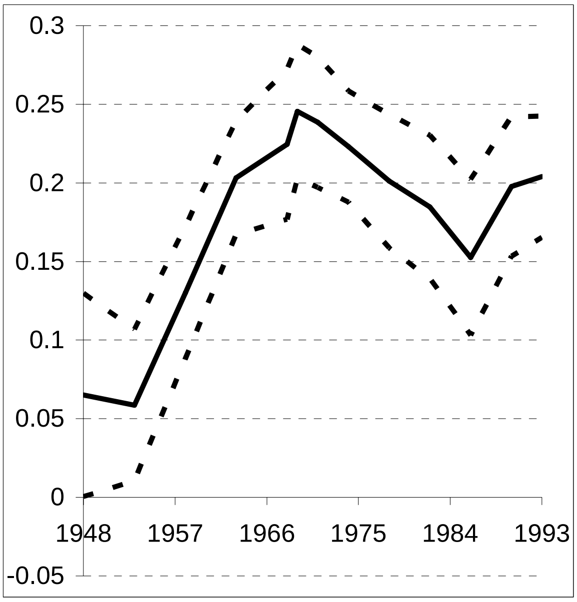


Figure 3. The effect of cognitive ability with 95 percent confidence interval. Dependent variable is log yearly earnings for men

a) Unconditional effects



b) Conditional on years of education

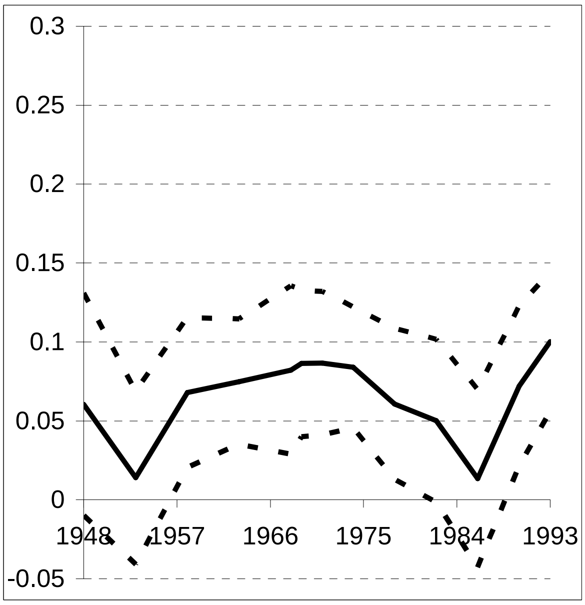


Figure 4. The return to education, unconditional and conditional on ability

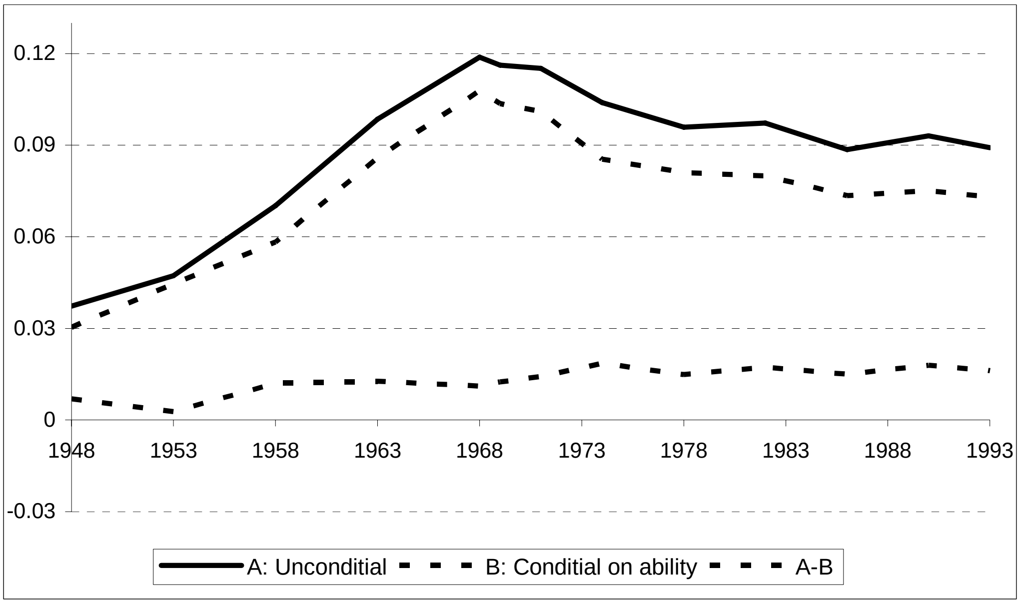


Figure 5. The effect of ability over the life-cycle, semi-parametric and parametric models. Dependent variable is log yearly earnings for men

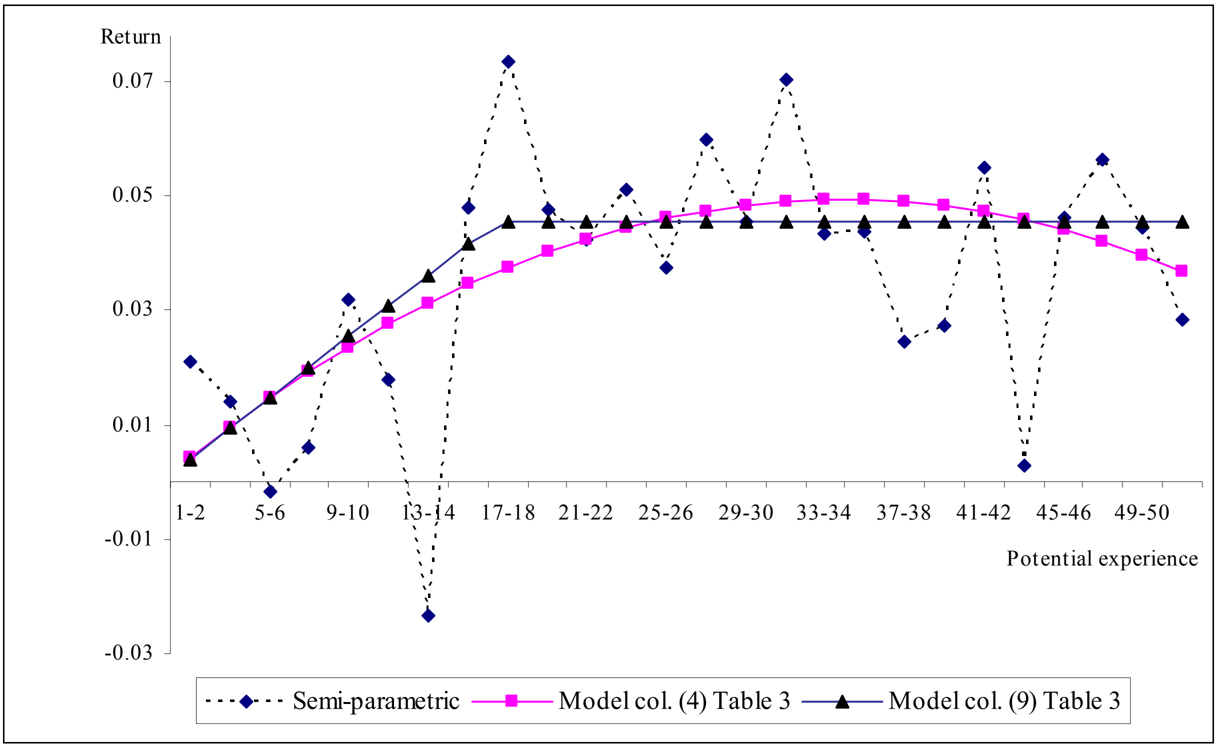


Figure 6. The effect of ability over the life-cycle, semi-parametric and parametric models. Dependent variable is rank in the wage distribution for men

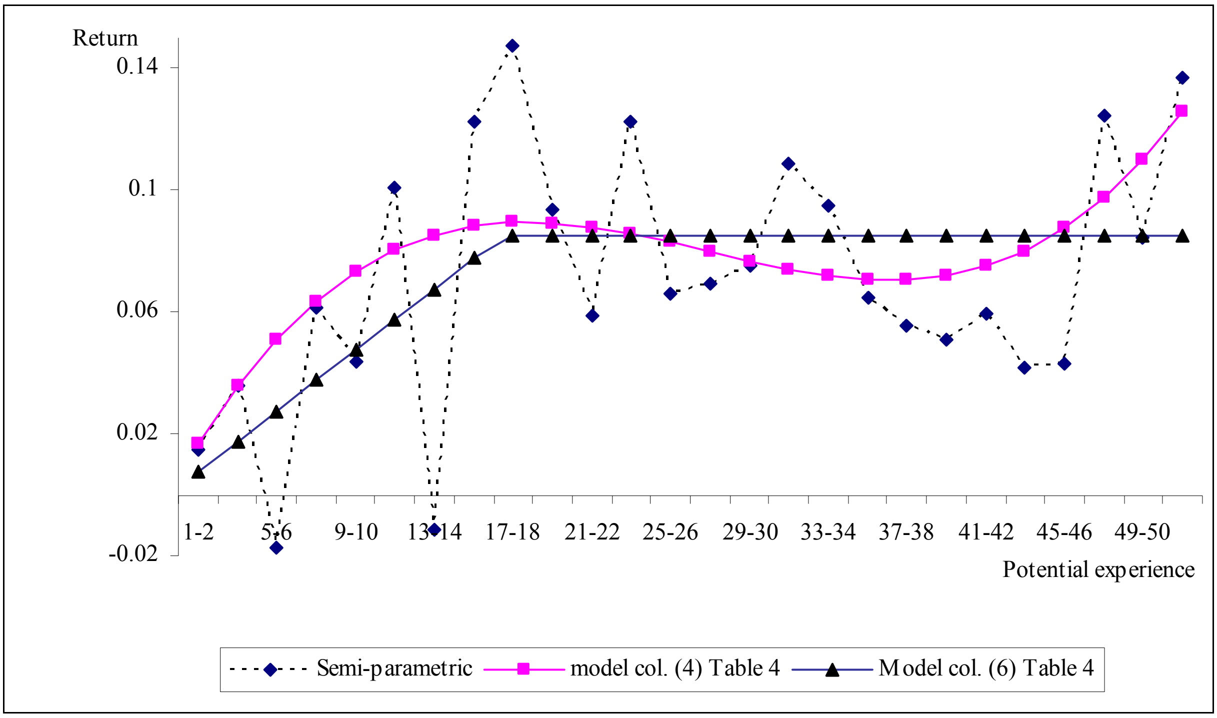
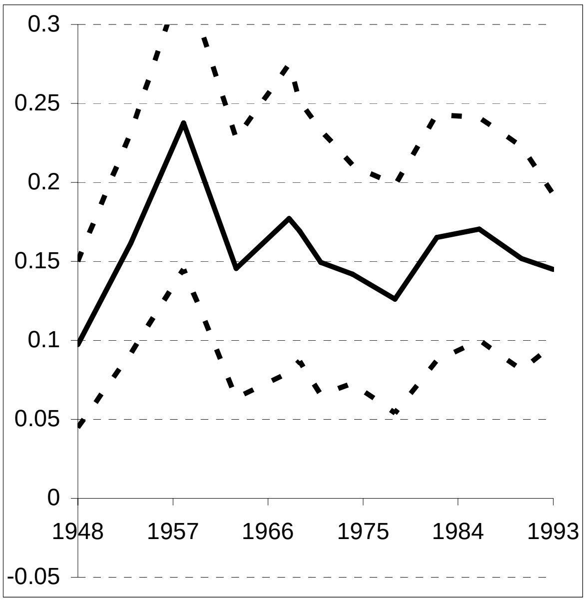


Figure 7. Unconditional return to ability with the 95 percent confidence interval. Dependent variable is log yearly earnings for women

a) All women



b) Excluding observations of part-time work

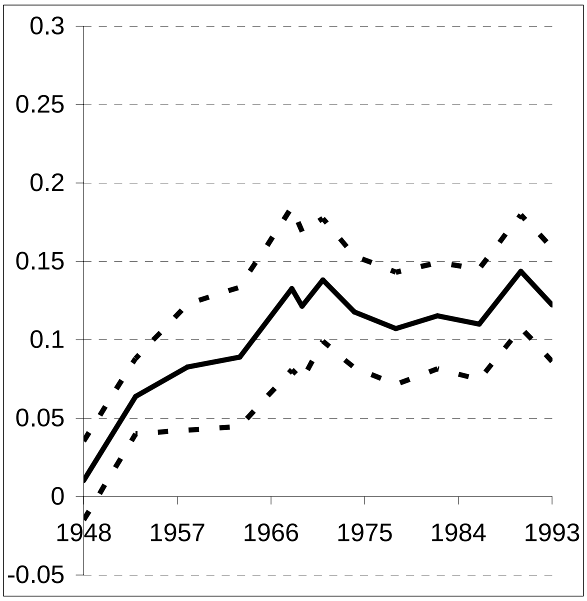


Figure 8. The effect of ability over the life-cycle, semi-parametric and parametric models. Dependent variable is log yearly earnings for women