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Torberg Falch and Sofia Sandgren Massih

UCLS

Uppsala Center for Labor Studies
Department of Economics
Uppsala University
P.O. Box 513
SE-751 20 Uppsala
Sweden
Fax: +46 18 471 14 78

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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. Cognitive ability measured at an early age is not influenced by the individual's choices of schooling. 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; employer learning

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[a] Department of Economics, Norwegian University of Science and Technology, N-7491 Trondheim, Norway. E-mail: torberg.falch@svt.ntnu.no

[b] Department of Economics, Uppsala University, P.O. Box 513, SE-751 20 Uppsala, Sweden, Royal Institute of Technology, Stockholm, and Department of Economics, Norwegian University of Science and Technology. E-mail: sofia.sandgren@nek.uu.se

1. Introduction

Information on the productivity of individuals entering the labor market is limited. Novice workers have no work history to prove their competence and abilities. Over time, employers can learn more about individual workers ('employer learning') as argued by Farber and Gibbons (1996) and Altonji and Pierret (2001), and workers may learn more about their own productivity ('employee learning') and change their wage claims and career plans accordingly. Then hard-to-observe characteristics relevant for productivity will be increasingly rewarded as they are revealed by the market when workers gain experience.

Empirical research is limited by availability of variables observable for researches but hard to observe for the actors in the labor market. The existing evidence is mainly based on the US Armed Forces Qualifying Test (AFQT) in the National Longitudinal Survey of Youth 1979 (NLSY79). Farber and Gibbons (1996) and Altonji and Pierret (2001) argue that AFQT is correlated with productivity but not observed by the market. In this paper we use a completely different data set to estimate the relationship between experience and the return to cognitive ability.

Our data consist of all pupils in the third grade in 1938 in the city of Malmö, Sweden. The data include several cognitive ability measures from the third grade, including an IQ test, teacher grading, and teacher subjective evaluations. The data have some advantages compared to NLSY79. First, we can estimate returns over the life-cycle since the individuals are followed to the age of 65. Second, our hard-to-observe variables are measured at an early age when the individuals are enrolled in primary school. In contrast, NLSY79 consists of individuals aged 15-22 when they conducted the AFQT test. Winship and Korenman (1997) and Hansen et al. (2004) find that schooling has a strong effect on AFQT,[1] a finding that is in accordance with the view among psychologists that environmental factors influence intelligence, see for example Sternberg and Grigorenko (2001). In this case the return to AFQT will to some extent capture the return to schooling. In addition, the correlation between the AFQT score and the productivity in the labor market decreases in the amount of schooling undertaken after the test. AFQT will be weaker related to the wage in observations with low experience (much schooling) than in observations with high experience (little schooling), spuriously pointing in the direction of market learning.

[1] Other papers using other data sets find the same effect, see for example Griliches and Mason (1972), Griliches (1976) and Falch and Sandgren (2006).

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 empirical results. We estimate how the effect of a compound measure of cognitive ability in third grade depends on experience using both semi-parametric and parametric specifications, we split the sample according to gender and education level, and we use different measures of early cognitive ability. Finally we investigate whether early cognitive ability is related to the probability of holding a supervisory position. Section 5 concludes.

2. Empirical approach

Productivity is related both to observable and unobservable individual characteristics. Over time, the actors in the labor market learn about unobserved characteristics by observing actual productivity. Better estimates on characteristics that are not directly observable will change the return to observed characteristics that are correlated with the hard-to-observe variables.

Assume that the true logarithm of productivity f_{it} of worker i at time t is

$$f_{it} = \alpha Z_i + \beta S_i + h(x_{it}) + \varphi_t + \mu_{it}, \quad (1)$$

where Z_i is cognitive ability, S_i is schooling, x_{it} is experience, $h(x_{it})$ is the experience profile of productivity, and μ_{it} is an iid productivity shock. φ_t reflects that average productivity increases over time. x_{it} is uncorrelated with Z_i and S_i when the individual characteristics are time-invariant.

The expectation about Z may depend on S and improve as more noisy signals about true productivity arrive. Expected productivity can on general form be written

$$E(f_{it} | S_i, x_i, \varphi_t) = a_i(x_{it}) + b(x_{it})S_i + h(x_{it}) + \varphi_t + \eta_{it},$$

where $a_i(x_{it})$ represents the noisy estimate of αZ_i, and $b(x_{it})$ depends on the learning process. Since learning improves the knowledge of Z_i, and learning takes place as experience increases, the actors can rely less on variables that are correlated with Z for experienced workers than for novice workers.[2]

[2] See Farber and Gibbons (1996), Altonji and Pierret (2001), Lange (2007), Schönberg (2007), and Pinkston (2009) for more detailed descriptions of market learning processes.

In this paper we are interested in how the effect of early cognitive ability on wages depends on experience. Thus, we estimate the model

$$w_{it} = A(x_{it})Z_i + B(x_{it})S_i + h(x_{it}) + \varphi_t + \varepsilon_{it},$$

with various restrictions on $A(x_{it})$. With market learning on Z, $\partial A/\partial x \geq 0$, $\partial B/\partial x \leq 0$, and the second derivatives depend on the noise in the productivity signals.

3. Data

We use the Malmö Longitudinal Data-set, possibly the longest longitudinal data-set existing.[3] The data include all children in third grade in Malmö municipality in 1938, originally 1,542 individuals. The data collected in 1938 includes information on family background as well as different cognitive 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.[4] A host of other information, as education level and work experience, were collected in four different questionnaires distributed in 1964, 1971, 1984 and 1994. The response rates for the questionnaires have been high, around 75 % each time. The IQ test conducted 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.[5] When the original information was collected in 1938, each child in third grade in any school within the municipality of Malmö was included. The IQ measure is available for the whole original cohort of third graders, with the exception of seven girls.[6] The test was constructed after thorough testing on third-graders the year before and 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

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

[4] During the empirical period, Malmö was the third most populous city in Sweden. The municipality consists of mostly urban areas, but also some rural parts. Manufacturing used to be an important part of the local economy, and one of the world's largest shipyards was located in the city in the 1950s and 1960s. Malmö was hit relatively hard by the recession in the 1970s, and the population fell from 265,000 inhabitants in 1971 to 229,000 in 1985. Since 1995, the regional economic growth has been relatively high, probably as a result of the new bridge across Öresund that has made Copenhagen–Malmö an integrated economic area.

[5] 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 are born earlier and 1.8 and 2.0 percent are born later. The large number of over-aged students is probably due to class repetition.

[6] These girls had average scores on the other cognitive 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 pupils 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 empirical analysis we will mainly rely on one compound variable of cognitive ability. A principal component analysis on standardized values yields very similar weights for the four different ability measures. Thus, we simply calculate the mean of the individuals' standardized values of the ability measures and denote this variable Early cognitive ability. 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 register data on annual earnings from 13 different years.[7] For the first years, 1948, 1953, 1958 and 1963, only the tax registers in 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 the national tax register and Statistics Sweden, and the data are almost identical.[8] The earnings in the data seem reasonable representative for Sweden.[9]

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[7] Earnings register data are collected in 1948, 1953, 1958, 1963, 1968, 1969, 1971, 1974, 1978, 1982, 1986, 1990, and 1993. We do not have information on hours of work, hence not on part-time work. The problem of having data on annual earnings instead of hourly earnings is likely to be most pronounced for women because they work part-time to a much larger degree than men. Among the men 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 earnings 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.

[8] 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

Figure 1 presents the standard deviation of log earnings. The standard deviation for men varies from 0.45 to 0.65, 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 varying labor supply over the time period. The general decline in the earnings dispersion in Sweden in the 1970s, see Edin and Holmlund (1995) and Hibbs and Locking (1996), is hardly visible for this cohort, but a raising trend stops around 1970.

In the conditional model estimated below the return to cognitive ability is related to experience. We will mainly rely on potential experience. When constructing potential experience we take possible grade repetition up to grade three into account.[10] 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 in the cross-section.

We will also report results for models replacing potential experience with actual experience. Actual experience may include information to the employers about worker quality and effort because it is an outcome variable itself. In particular one would expect grade repetition towards the end of compulsory schooling to convey information relevant for employers. Actual experience is calculated using occupational information given in the questionnaires, which implies that there are some missing observations.[11]

Educational information is collected from both the questionnaire in 1964 and school registers, and information is missing for only 3.5 percent of the original sample. Figure 2 presents the

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levels in the data, while in 1969 there are 106 earning levels. From 1971 and onwards, the precise earning is reported and includes taxable benefits such as unemployment benefits. Before 1971 benefits were not taxable and thus not registered in the tax registers.

[9] In 1982, the average earnings for men in the sample is 103,000 SEK with standard deviation of 59,000. In the original sample, 87 percent was born in 1928. According to Statistics Sweden, the average earning in 1982 of all men in Sweden born in 1928 was 93,000 SEK with standard deviation of 66,000. The slightly higher average wage in the Malmö data is likely due to lower wages in rural than in urban areas.

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

[11] When calculating actual experience, we have made some assumptions. For the period up to 1951, we have assumed that the individuals 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. Nevertheless, we have missing values for 24 and 28 percent of the observations for men and women, respectively. Those who have not answered the questionnaires have somewhat lower scores on the ability measures and less education and earnings than 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.

number of observations for which there is information on earnings, education 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.[12] 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. 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.[13]

Table 2 presents descriptive statistics for the variables used in the analysis, both for the original sample and for the sub-sample of individuals with all necessary information to be included to the analysis. The differences between the samples are in general small. We classify education into different types. 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. Lower secondary education was most common among women, higher education was most common among men, actual experience is lower for women, and women work part-time to a larger extent.

One typical challenge in identifying changes in the return to cognitive 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 enrolled in third grade in 1938. To distinguish between time effects and changes in the return to ability, we specify a model with time specific effects, the third polynomial of experience, and interaction effects between experience and all other variables. Thus, the model includes

[12] The educational types requiring 12 years of schooling were typical female professions such as hospital nurses.
[13] The number of men and women, respectively, included in the analysis is 259 and 241 in 1948, 354 and 308 in 1953, and 478 and 259 in 1958. Thereafter it is 630-700 observations of men except in 1993 with 589 observations. For women, the number of observation increases about linearly from 1958 to the mid 1970s, and is about 530 thereafter.

time specific effects of potential experience, which makes years of education collinear in the model, and captures the interaction $B(x_{it})S_i$ in equation (3).

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

We start out by focusing on the sample of men in Section 4.1–4.4, and estimate similar models for women in Section 4.5. Firstly we present unconditional returns to Early cognitive ability at different ages. Thereafter we estimate conditional models. We investigate whether the relationship between experience and the return to cognitive ability is sensitive to the handling of experience, education, part-time work, and individual characteristics, and estimate models distinguishing between different cognitive ability measures.

4.1. Unconditional return to cognitive ability and education

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

Some of the return to cognitive 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. The correlation of Early cognitive ability and years of education is slightly above 0.5.[14] Figure 3b presents the return 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 lower in the conditional model, and increases to a smaller extent in the 1950s and 1960s.[15] A major effect of cognitive ability in economic terms seems to be on educational choices.

One hypothesis from Section 2 is that the return to education declines in experience in model that include variables that are hard to observe in the market. This prediction relies, however,

[14] Heckman and Vytlacil (2001) make the point that if the relationship between education and cognitive ability tests becomes too strong, it is impossible to disentangle the effects of education and ability tests. In our data individuals with highest cognitive ability are distributed across all types of schooling.

[15] 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.

on the assumption that the true effect on productivity is constant. 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. Figure 4 presents the unconditional return to education, which increases up to the age of 40 in 1968, and decreases slightly thereafter. Figure 4 also presents the results from the model conditioning on Early cognitive ability, the same model as in Figure 3b. The return to education is lower in the conditional model each year, and there is a tendency of an increasing difference as one would expect. 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 Early cognitive ability and potential 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 allows for separate effects of the dummy variables for the two-year interval in potential experience, and includes a cubic polynomial in potential experience. In addition, the model includes dummy variables for educational type, never being married, working part-time, retiree, and year. All variables are interacted with potential experience.

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 15-36 years of potential experience, 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.[16] The estimate is below the results in Altonji and Pierret (2001) and Schönberg (2007), which is based on tests taken later in life and captures elements of non-compulsory educational choices. 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. 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 for the interaction terms. The return to ability is maximized at about 35 years of potential 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 this effect is insignificant.[17]

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. The models are illustrated in Figure 5 above. They are very similar and impossible to distinguish statistically.

[16] This estimate cannot directly be interpreted as the mean of a random individual because the attrition is lower in the start of the empirical 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.

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

The models presented so far do not include education directly because education and potential experience are perfectly correlated each year and the models include interaction terms between year and potential experience.[18] The interaction between education and experience can be identified, however, by excluding the interaction between year and potential 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 cognitive ability, and the interaction between education and experience is negative as predicted by the theory. Further, the interaction effect is not sensitive to the handling of ability. The results indicate that the schooling and ability coefficients are not driven by the same learning process over the life-cycle. In the following we use the initial and more flexible model formulation.

The seemingly decline in the return to Early cognitive ability in the last years of the working life in Figure 5 may come about by the overall compression of the wage distribution that took place in Sweden during the 1970s.[19] The compression 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. If union influence has changed over time, it may be difficult to interpret the interaction effect between ability and experience because the effect of ability at different experience levels to some extent is identified at different points in time.

Figure 5 indicates low return to ability for potential experience of 37-44 years. However, individuals with only primary education had potential experience of 37 in 1980, at the end of the period with wage compression in Sweden. The low return to ability for potential experience of 37-44 years can therefore hardly be related to the overall wage compression in the 1970s. Falch and Sandgren (2008) estimate models using the rank in the wage distribution as the dependent variable, a variable that is less sensitive to overall changes in the density of

[18] The studies using NLSY identifies the effect of education on individuals conducting 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.

[19] 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 earnings distribution, but the results do not support that the compression of the wage distribution in the 1970s affects the estimated return to ability over the life-cycle.

4.3. 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 4 presents 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 models in Column (1) in Table 4 are 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 interacted with actual experience as all other variables), without altering the results.

The last two columns of Table 4 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 5 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 cognitive 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 44 years of experience increases markedly. 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 5 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. 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 5 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 to cognitive 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.

4.4. Heterogeneity across education and cognitive ability measures

Hard-to-observe cognitive 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. In the second part we estimate models using the individual measures of cognitive ability instead of the compound measure. We also present results using our measure corresponding to the US AFQT test to facilitate comparison with the US studies.

Table 6 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.[20] There are clear differences in the return to ability between the two groups.

[20] 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 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 cognitive ability is maximized. In fact, the effect of the interaction with experience squared is clearly insignificant, indicating that that the return to ability is increasing over the whole life-cycle.

On the other hand, the return to cognitive ability to academically educated individuals 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 column (3) and the spline specification in column (5).

Our measure of cognitive ability is a compound variable based on four different cognitive ability measures in third grade. 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 relative performance in class? In Table 7 we present models using only one of the cognitive ability measures at time.

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 cognitive 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 is not the best characterization of the data.[21]

Lastly, Column (5) in Table 7 presents the results when using the IQ score at military enrollment as the measure of cognitive 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

[21] 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.

blacks and women. Thus, the results in Schönberg (2007) seem to be more comparable with the present study than Altonji and Pierret (2001).

Educational choices are likely to contribute to higher conditional return to IQ measured at age 20 than at age 10. Falch and Sandgren (2006) find that education has a major effect on IQ at age 20 in the present data, which implies that return to IQ at age 20 in part captures the return to education. In unconditional models, we find that the average returns to IQ at age 10 and 20 are 0.19 and 0.20, respectively, the same as the return to our compound ability measure. This also indicates that the difference in the estimated returns to cognitive abilities at ages 10 and 20 is related to educational choices. Regarding the return to IQ at age 20 over the life-cycle, the pattern is similar to ability measured at age 10.

4.5. Return to cognitive ability 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. Figure 6 presents the unconditional return to cognitive ability for women. Figure 6a 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 3a, and it is hard to interpret the results as being in accordance with the hypothesis of market 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 investigate the latter hypothesis. In Figure 6b, observations with part-time work are excluded. Then the picture is similar to that for men, although the return is lower.

Figure 7 and Table 8 present results for conditional models. Figure 7 shows that, compared to men, the return to cognitive ability is low for high and low potential experience levels. However, column (1) in Table 8 shows that the average conditional return is slightly higher for women than for men. It follows from Figure 7 that a functional form with interaction between ability and squared potential experience gives a reasonable fit to the data, and in columns (2) and (4) in Table 8 both interaction terms are highly significant.

The correlation coefficient between actual and potential experience is 0.70 for women, clearly lower than for men. Table 9 shows, however, that by simply replacing potential experience with actual experience, the estimated coefficients do not change much. The largest change is that the quadratic interaction term becomes insignificant. In the last part of Table 9, 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 cognitive ability for women 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 cognitive 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 10 presents the results. One standard deviation in Early cognitive ability increases the probability to have a supervisory position by 3.2 percent for men and 2.6 percent for women. The effect is significant at 10 percent level for men. The effect seems to be larger for academically educated than for vocationally educated, but is not statistically significant for neither of the groups.[22]

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

[22] 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.

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 cognitive ability at age 10 on earnings at ages 20-65 for a Swedish cohort. The average unconditional return over the life-cycle to one standard deviation of early cognitive ability is about 20 percent, but our results clearly indicate that most of the effect goes trough educational choices. The average return conditional on, inter alia, education and experience, is only about 4 percent.

We find that the conditional return to early cognitive ability increases the first 15-25 years after finishing school. This result is in accordance with the hypothesis that cognitive ability is revealed by the labor market as workers gain experience. It seems like no more learning takes place after 25 years. We find that the return to early cognitive ability over the life-cycle is similar for men and women, but highest for individuals with academic education. Cognitive ability seems to have a positive impact on the probability of being employed in a leader position, but this effect only explain a small part of the return on earnings.

We find lower conditional return to cognitive ability than typically found in other studies. The difference may partly be related to the types of skills being tested and the timing of the tests. Previous studies have used the AFQT score in NLSY, which are conducted after schooling choices are made. When schooling choices affect test scores, the return reflects both early cognitive ability and individual educational choices. Thus, the return to cognitive ability may be overestimated in the sense that it partly includes the return to education. In addition, the fact that the AFQT test is conducted at different ages may overestimate the speed of market learning with standard estimation methods.

We leave to future research to investigate why the return to cognitive ability is increasing in experience. Market learning is only one potential explanation. Hause (1972) argues that experience and cognitive 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 inter-temporal choices of investment in earnings potential. The access to or benefits from on-the-job-training may depend on learning capacity.

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

	Obser-vations	Mean	Standard deviation	Correlation coefficients				
				IQ 10	GPA	Rating O	Rating W	Ability
IQ in third grade (IQ 10)	1,535	98.1	16.37					
Grade point average third grade (GPA)	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
Early cognitive ability	0.01 (0.99)	-0.01 (0.99)	-0.01 (1.02)	-0.06 (1.01)
Potential experience in years, 1993	49.1 (2.5)	48.9 (2.7)	49.3 (2.0)	49.3 (2.1)
Actual experience in years, 1993	45.2 (2.5)	44.8 (6.7)	33.9 (12.6)	33.5 (12.4)
Years of education	8.1 (3.3)	8.9 (2.6)	7.7 (3.2)	8.7 (2.1)
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
Working part-time	-	0.07	-	0.35
Retired, 1993	0.60	0.63	0.55	0.56
Marital status – have never been married	0.09	0.09	0.06	0.04
Number of individuals	834	726	708	602

Note. The subsamples consist of the individuals without missing observations for any of the reported variables or earnings.

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 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, marital status, year specific effects, a imputed dummy variable for part-time work, a dummy for early retirement, and three dummy variables for educational type (only columns (1)-(9)). 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 specification 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	$0.409^{\sim}$	0.220
	(0.273)	(0.274)	(0.214)	(0.203)
Experience squared / 100	-0.0073	-0.0063	$-0.0059^{\sim}$	-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 5. The specification 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 6. 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 7. The returns 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~ (0.010)	0.031** (0.011)	0.032** (0.011)	0.049** (0.011)	0.074** (0.013)
R^2	0.5610	0.5621	0.5541	0.5586	0.5291
Cognitive ability	-0.001 (0.025)	-0.008 (0.027)	0.012 (0.021)	0.017 (0.027)	0.005 (0.032)
Interaction between Cognitive ability and					
Potential experience/100	0.200 (0.187)	0.228 (0.192)	0.157 (0.167)	0.136 (0.200)	0.405~ (0.209)
Potential experience squared/100	-0.0038 (0.0030)	-0.0029 (0.0030)	-0.0026 (0.0027)	-0.0009 (0.0031)	-0.0051 (0.0033)
R^2	0.5611	0.5623	0.5541	0.5588	0.5296
Interaction between Cognitive ability and					
Potential experience / 100	0.191* (.083)	0.177* (0.084)	0.238** (.084)	0.250** (.092)	0.441** (.121)
Potential experience squared / 100	-.0036* (.0018)	-0.0021 (0.0018)	-.0038* (.0018)	-.0026 (.0019)	-.0056* (.0026)
R^2	0.5611	0.5623	0.5541	0.5588	0.5295
Early cognitive ability	-0.017 (0.030)	-0.026 (0.032)	0.009 (0.025)	-0.003 (0.032)	-0.025 (0.036)
Interaction between Early cognitive ability and Potential experience up to 17 / 100 (spline)	0.225 (0.200)	0.352~ (0.209)	0.143 (0.182)	0.321 (0.216)	0.621** (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* (0.063)	0.197** (0.069)	0.200** (0.072)	0.305** (0.071)	0.467** (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 8. 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 9. 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**	-0.006	-	-0.087*	-
	(0.017)	(0.051)		(0.037)	
Interaction between Early cognitive ability and					
Actual experience / 100	-	0.402	0.447*	-	-
		(0.442)	(0.219)		
Actual experience squared / 100	-	-0.0073	-0.0080	-	-
		(0.0088)	(0.0060)		
Actual experience / 100. Linear to 17, constant thereafter	-	-	-	0.742**	0.295**
				(0.223)	(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
B. Vocational education					
Early cognitive ability	0.024	-0.042	-	-0.045	-
	(0.016)	(0.040)		(0.043)	
Interaction between Early cognitive ability and					
Potential experience / 100	-	0.630~	0.360*	-	-
		(0.343)	(0.158)		
Potential experience squared / 100	-	-0.0115*	-0.0075*	-	-
		(0.0058)	(0.0035)		
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	0.429	0.159
				(0.306)	(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
C. Academic education					
Cognitive ability	0.106**	-0.186**	-	-0.189**	-
	(0.030)	(0.064)		(0.062)	
Interaction between Early cognitive ability and					
Potential experience / 100	-	2.323**	1.013**	-	-
		(0.611)	(0.332)		
Potential experience squared / 100	-	-0.0388**	-0.0182*	-	-
		(0.0117)	(0.0080)		
Potential experience / 100. Linear to 17, constant thereafter	-	-	-	1.865**	0.721**
				(0.457)	(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 10. 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

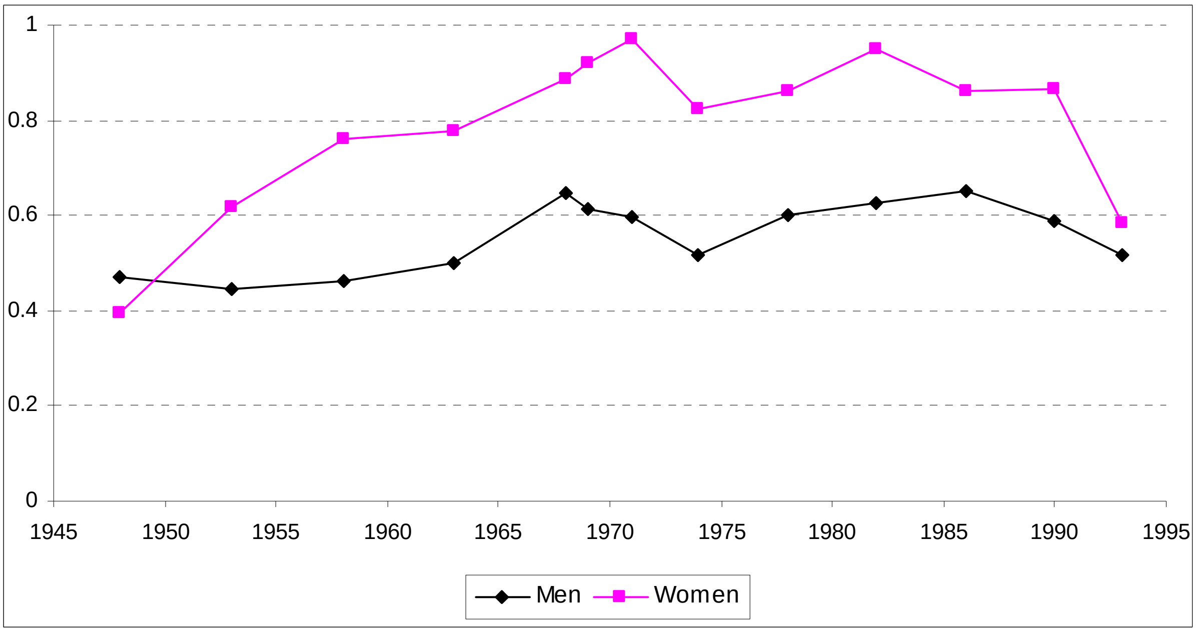


Figure 2. The number of observations for each level of potential experience

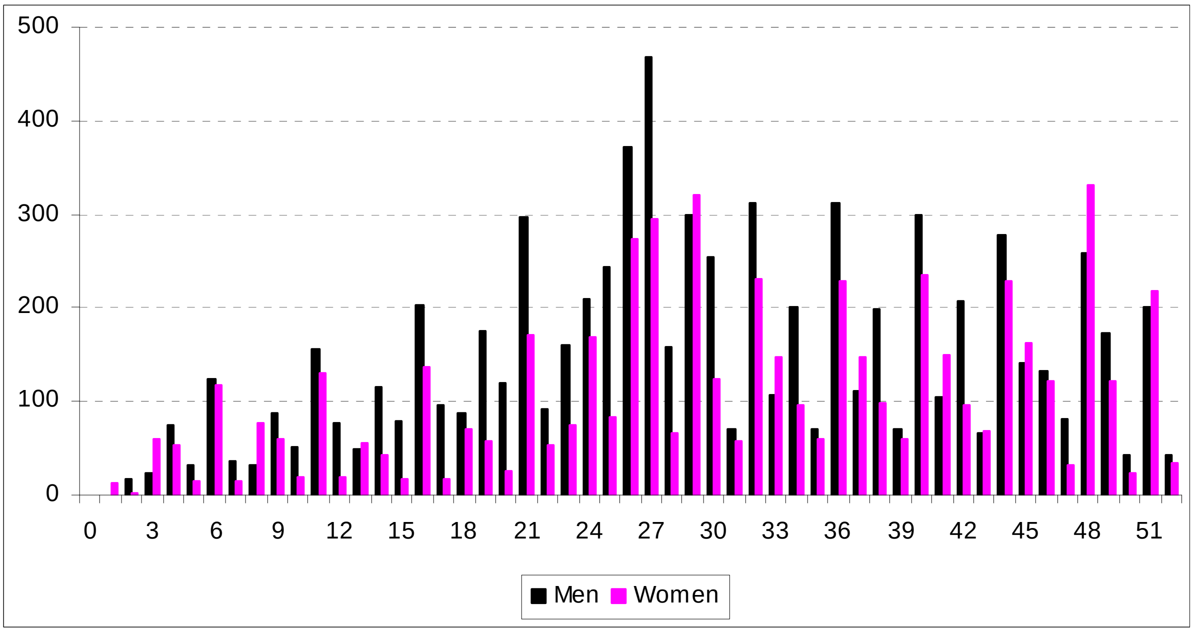
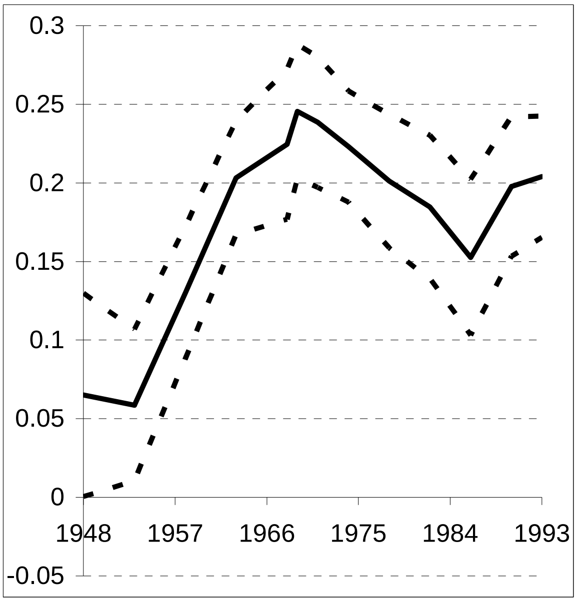


Figure 3. The effect of cognitive ability with 95 percent confidence interval. Dependent variable is log yearly earnings for men

a) Unconditional effects



b) Conditional on years of education

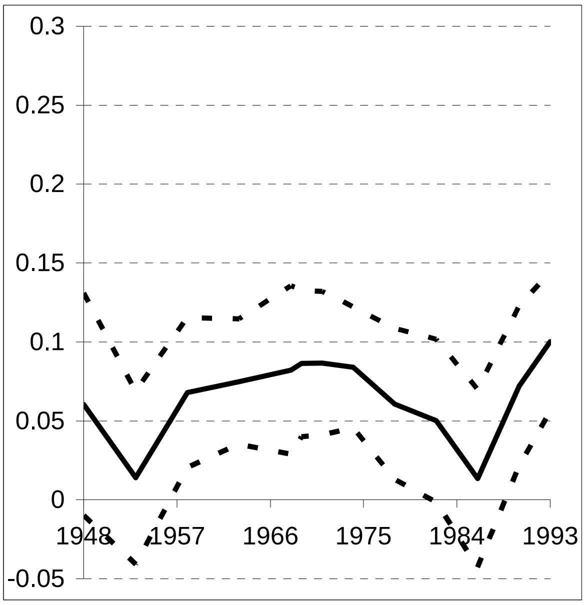


Figure 4. The return to education, unconditional and conditional on cognitive ability

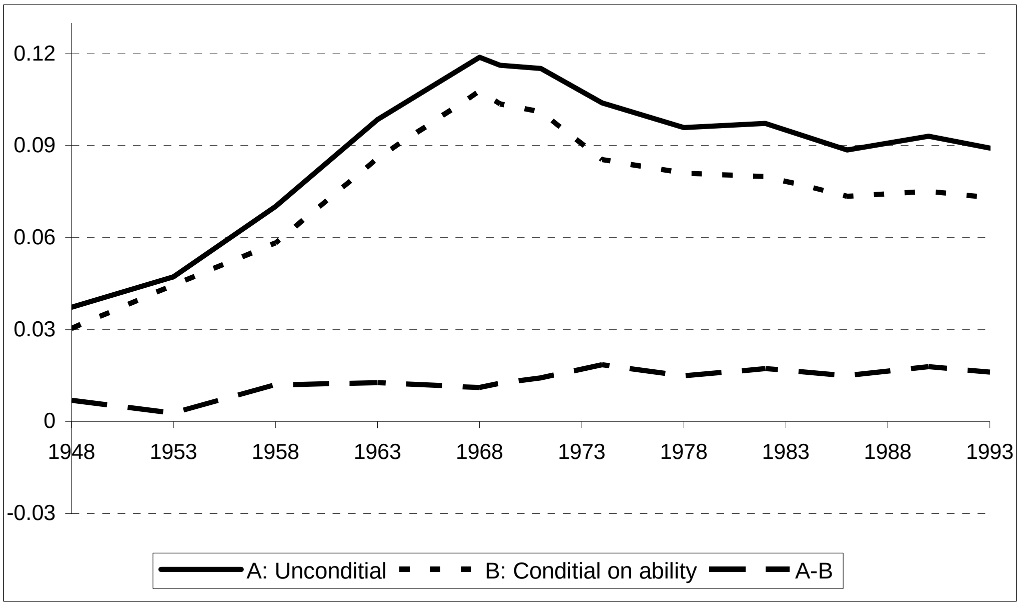


Figure 5. The effect of ability over the life-cycle, semi-parametric and parametric models. Dependent variable is log yearly earnings for men

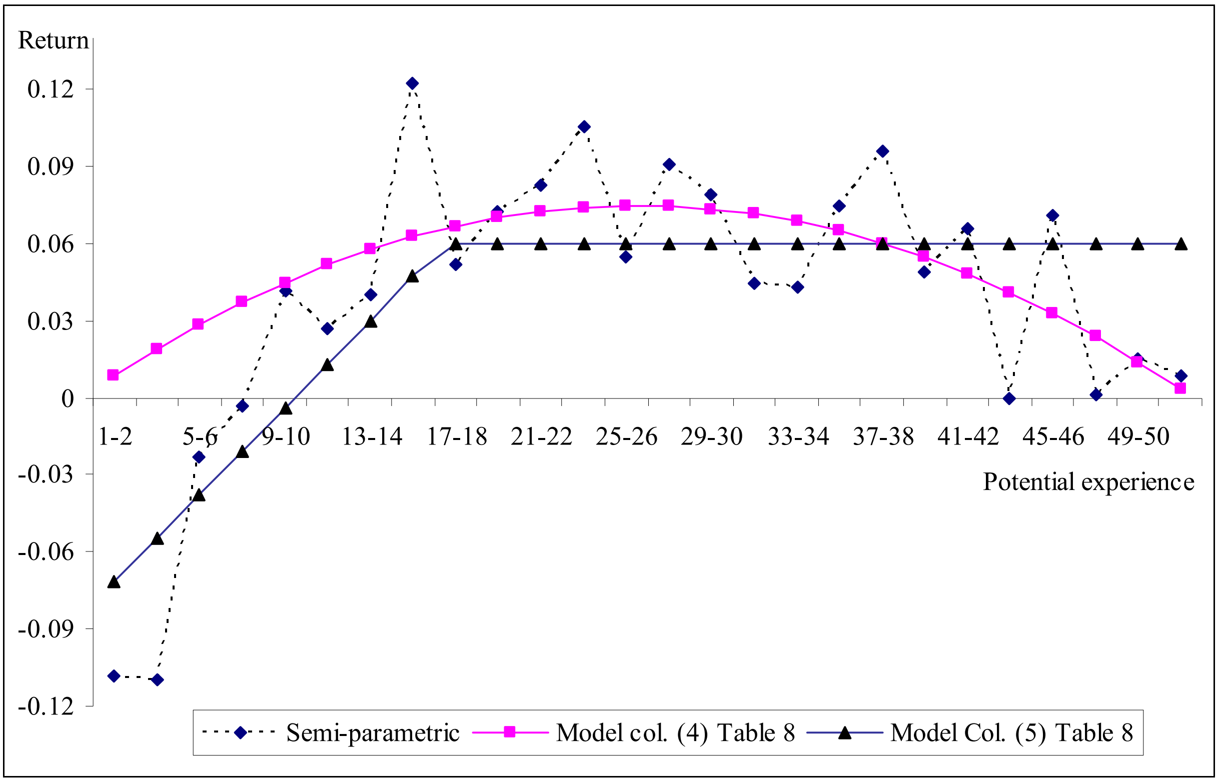
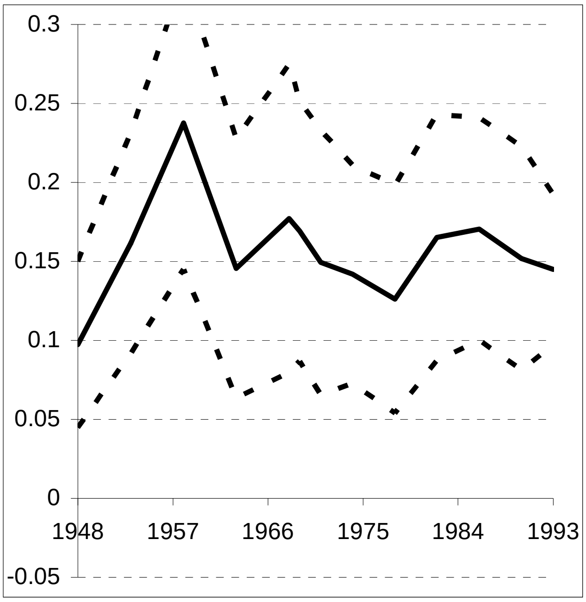


Figure 7. Unconditional return to cognitive ability with the 95 percent confidence interval. Dependent variable is log yearly earnings for women

a) All women



b) Excluding observations of part-time work

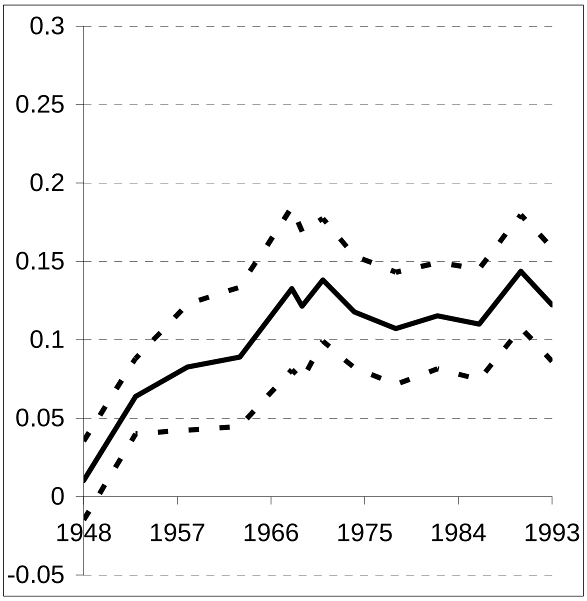
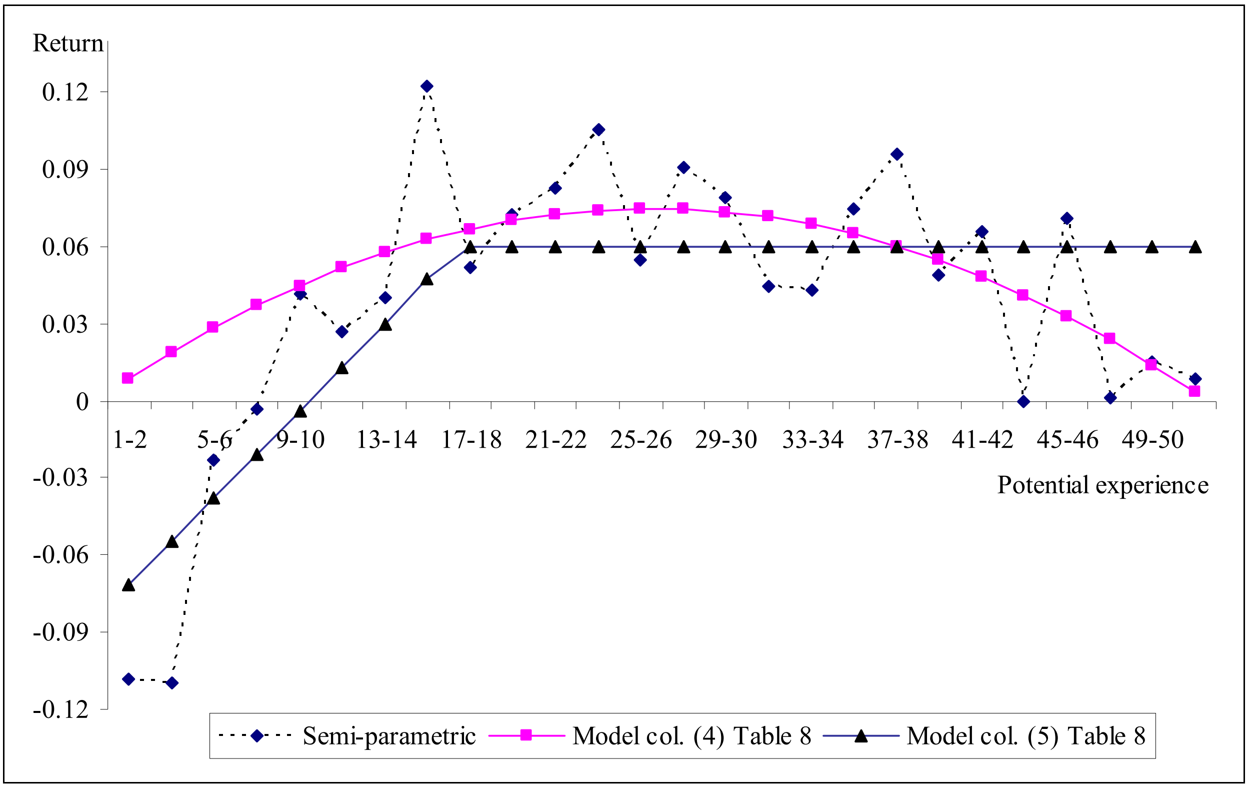


Figure 8. The effect of cognitive ability over the life-cycle, semi-parametric and parametric models. Dependent variable is log yearly earnings for women



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