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The Effect of Schooling on Earnings: Evidence on the role of family background from a large sample of Norwegian twins

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A large representative sample of Norwegian twins is used to estimate the causal effect of schooling on earnings in Norway, separately for men and women. The within-twin-pair estimates reveal that standard cross section (OLS) estimates of the schooling effect on *male hourly earnings* are biased upwards. For women, no such bias is found. However, family background appears to affect both educational attainment and post-schooling labour supply of women, implying that the standard estimate of the effect of schooling on *female annual earnings* is upward biased. JEL-codes: J31, J24, I21

Numerous studies confirm that better-educated people are more successful in the labour market, see Asplund and Pereira (1999) and Ashenfelter and Rouse (1999) for recent European and U.S. evidence. Educational attainment is determined by individual decisions and preferences but opportunities, schooling costs and effects on earnings may differ across individuals. Unobserved heterogeneity implies that the positive correlation between individual labour market success and educational attainment *can* be spurious. The fundamental problem of causation arises: Is the more successful labour market performance of the better-educated an effect of more schooling or do innately successful individuals acquire more education? In the latter case, estimates of return to schooling in

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standard earnings equations will be upward biased, typically labelled "ability bias" in the literature. When the individual effect of schooling is upward biased, it will exceed the productivity improvements from educational investments. Of course, the social return to educational investments may differ from the causal effect on individual earnings for other reasons like externalities or general equilibrium effects.

In standard empirical earnings equations, the estimate of the average marginal effect of schooling on earnings is biased if unobserved earnings capacity is correlated with years of schooling. Moreover, if individuals are different with respect to the human capital they acquire from a given level of schooling, the standard estimate is biased upwards simply because those who benefit more tend to stay in school longer. Those with low returns will tend to quit school earlier. As highlighted by Card (1999), the ability bias can be due to both an "earnings capacity", and a "return-heterogeneity" bias.

Our empirical strategy is motivated by the fact that family background is an important determinant of earnings capacity and possibly also the return to schooling. Intergenerational as well as intragenerational earnings correlations, looking at parents/children and siblings respectively, suggest that characteristics shared by members of the same family, explain a substantial part of the variation in the socio-economic success of individuals, see Solon (1999) and Björklund and Jännti (2000). It is also widely accepted that family background variables like parental schooling and earnings are important determinants of educational attainment, see e.g. Nordli Hansen (1997) and Mayer (1998) for recent Norwegian and U.S evidence respectively.

We study the causal effect of schooling on earnings and the ability bias in standard earnings equations by means of a large representative sample of Norwegian twins. The twin approach is based on the "Pure Family Effects" (PFE) assumption, Card (1999). PFE means that twins of the same gender have equal expected earnings capacity, for all levels of educational attainment. Moreover, under PFE the impact of schooling on earnings is the same for both twins. The PFE assumption implies that an unbiased estimate of the causal effect of schooling on earnings can be obtained by comparing the earnings differential between twins with their difference in educational attainment. While twin samples usually come from surveys based on Medical Birth registers, or even twin assemblies, our data are created by a matching of several official Norwegian registers. These registers cover the whole Norwegian population aged 16–69 and include day of birth and a link to parents. Twins are defined as individuals born at the same, or the next/previous, day by the same mother. Our twin pairs are therefore biological twins, not necessarily reared together, and we have no information about zygosity ("identical" or "fraternal" twins) at the individual level. We are able to check whether twins are representative for the population at large because similar data are available for both twins and non-twins. The large samples allow us to estimate returns to schooling for women and men separately.

Studies of return to schooling typically estimate a linear model where an extra year of schooling is assumed to give the same percentage earnings increment at all levels of educational attainment. Although linearity seems to be reasonable for some countries like the U.S., previous Norwegian studies indicate a flat region at around 13–15 years of schooling, see Asplund et al (1996), Hægeland, Klette and Salvanes (1999). We therefore estimate a linear as well as a flexible model, i.e. without imposing restrictions on

the relationship between years of schooling and earnings.

The paper is organised as follows. The next two sections discuss the earnings-schooling relationship and the assumptions under which the twin approach offers an unbiased estimator of the causal effect of schooling on earnings. The main findings of previous studies are presented briefly, before we describe the Norwegian data on twins. The estimated returns to schooling, both from linear and non-linear models, are reported and then discussed in the concluding section of the paper.

The effect of schooling on earnings

We focus on the *average marginal effect of schooling on earnings* (b) in a standard earnings equation,

(1) $\ln(y_j) = a + bS_j + X_j\gamma + u_j$

where y_j is earnings of individual j, S_j is years of schooling, a is the common intercept, X_j is a vector of observables like experience and u_j represents unobserved earnings determinants. It is well known that standard OLS procedures yield unbiased estimates of the average marginal effect of schooling on earnings only if u_j is independent of S_j and X_j.

Because of individual heterogeneity, educational attainment can be correlated with earnings capacity as well as return to schooling. Following Card (1999), (1) can be generalised to

(2) $\ln(y_j) = a_0 + bS_j + X_j\gamma + \{a_j + (b_j - b)S_j\} + \varepsilon_j$

where a_j is an individual "earnings capacity" component (defined as difference from the average, a_0) with a zero mean, b_j is the individual return to schooling and ε_j measures unobserved earnings determinants that are uncorrelated with schooling. This formulation highlights two types of heterogeneity tied to earnings capacity (a_j) and return to schooling (b_j).[1] Average capacity and return are denoted a and b, respectively. Our interest is in b, i.e. *the average marginal return to schooling*, and focus will be on whether the OLS-estimate of b is (asymptotically) biased.[2]

A comparison of (1) and (2) offers an interpretation of the "error term", u_j, in the standard earnings equation. First, variation in expected return to schooling give rise to a "return heterogeneity bias" in the case of correlation between b_j and S_j. The impact on standard OLS estimate is illustrated in Figure 1 where high-return individuals are assumed to take more education (around B) than low-return individuals (around A). The Becker-type optimal schooling models predict that individuals with higher returns stay longer in school if they know their return (b_j) at the time when schooling decisions are made.

Second, the earnings capacity bias is due to correlation between a_j and S_j. The direction of the earnings capacity bias is, however, ambiguous. Most researchers seem to believe that this bias is positive because children from "high capacity" families have lower marginal cost of, or more taste for, schooling. Extending the Becker-approach, consider limited access to, as well as quality differences

1. The coefficient b is typically called "the return to schooling", but it coincides with the internal rate of return to a year of schooling investment only if (i) years of post-schooling labour force participation is independent of S and (ii) there are no direct costs of schooling and (iii) there is separability between years of schooling and experience in the earnings equation, see Willis (1986) and a critical discussion in Heckman et al (1999).
2. When the effect of schooling on earnings varies between individuals, the concept "return to schooling" can be defined in different ways. Our average marginal effect of schooling is different from the "effect of treatment (schooling) on the treated (schooled)", $E(b_j | S_j = s)$, partly because those who benefit most from schooling will tend to have higher S, see Heckman and Vytlacil (1998).

Figure 1.
Ability bias due to return heterogeneity

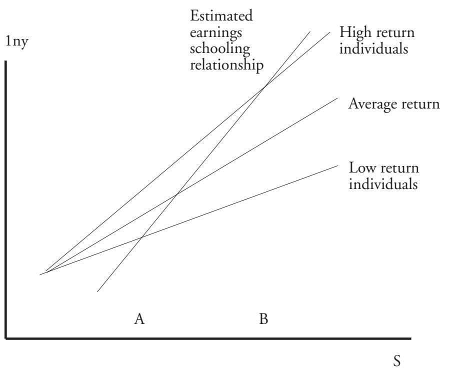
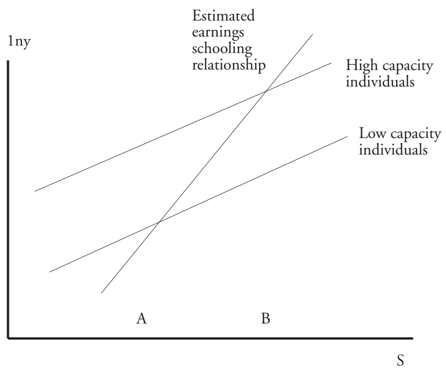


Figure 2.
Ability bias due to earnings capacity heterogeneity



across schools and universities. Although earnings capacity is different from cognitive ability, or performance in school, a positive correlation seems likely. Then, if access to colleges and universities is rationed on the basis of previous school performance, a positive relationship between schooling and earnings capacity will appear. Moreover, colleges of high quality may only be available to those with performance above a certain level during their first years in school. Consequently, ability is likely to be positively correlated with educational attainment.

$\ln(y_{i1}) = a_0 + bS_{i1} + X_{i1}\gamma + a_{i1} + (b_{i1} - b)S_{i1} + \varepsilon_{i1}$

Griliches (1977), on the other hand, points out that the marginal cost of schooling is higher for the more able individuals because their foregone income is higher. This opportunity cost argument suggests a negative correlation between earnings capacity and the level of schooling.

$\ln(y_{i2}) = a_0 + bS_{i2} + X_{i2}\gamma + a_{i2} + (b_{i2} - b)S_{i2} + \varepsilon_{i2}$

Figure 2 illustrates the case where earnings capacity is positively related to years of schooling, i.e low (high) capacity around A (B).

The standard OLS estimator attributes the earnings differential to differences in educational attainment, while a substantial part of it is due to the other unobserved factors behind the earnings capacity of individuals.

The Twin Approach: An application of the within-family estimator

The departure of the twin approach is that twins of the same gender have very similar personal characteristics. To fix ideas, rewrite (2) for twin 1 and 2 of family i;

(3) $\ln(y_{i1}) = a_0 + bS_{i1} + X_{i1}\gamma + a_{i1} + (b_{i1} - b)S_{i1} + \varepsilon_{i1}$

(4) $\ln(y_{i2}) = a_0 + bS_{i2} + X_{i2}\gamma + a_{i2} + (b_{i2} - b)S_{i2} + \varepsilon_{i2}$

Twin studies typically apply the "Pure Family Effects"(PFE)-assumption saying that earnings capacity and return to schooling are the same within families ($a_{i1}=a_{i2}$ and $b_{i1}=b_{i2}$), see details in Card (1999). In other words, variation in educational attainment within twin pairs is assumed to be caused by factors without direct influence on post-schooling labour market performance. Under PFE, the

impact of unobserved earnings capacity and return heterogeneity can be removed by simply taking differences between twin brothers, or sisters, in the same family;

(5) $\Delta \ln(y_i) = \ln(y_{i1}) - \ln(y_{i2}) = b(S_{i1} - S_{i2}) + (X_{i1} - X_{i2})\gamma + \varepsilon_{i1} - \varepsilon_{i2}$

$(y_i) = \ln(y_{i1}) - \ln(y_{i2}) = b(S_{i1} - S_{i2}) + (X_{i1} - X_{i2})\gamma + \varepsilon_{i1} - \varepsilon_{i2}$

Therefore, the first difference, or fixed effect, estimator provides an unbiased estimate of *b*. An alternative estimator is used by Ashenfelter and Rouse (1998). They include the total years of schooling for both twins as an additional variable in the earnings equations to capture the common family component shared by twins. The idea behind the within-family estimators can also be explained by means of figure 1 and 2. Under PFE, we compare individuals along the same schooling-earnings relationship.

The critical question is whether the "Pure Family Effects" assumption holds for twins. Monozygotic (identical) twins are genetically equivalent, and if they are reared together, they have also experienced the same environment during childhood. Dizygotic (fraternal) twins of the same sex are genetically like sisters/brothers, but, unlike many sisters and brothers, fraternal twins reared together enjoyed the same environment. Brother and sisters have frequently experienced a different family environment, both socially and physically. Families move, parents age and the size of the family changes as new children are born. Family income and wealth change over the life cycle of the parents, through savings or heritage. Thus, siblings of the same age (twins) are likely to have experienced a more similar environment than siblings in general.

The criticism of the PFE assumption emphasises that schooling effects are identified by twin-pairs where the two brothers or sisters end up with different educational attainment. Then, the crucial question arises: If twins were exposed to very similar environments when they grew up and some twins are even genetically identical, why is there any difference in schooling between twins? Several studies argue that even monozygotic twins are different as children, because they want to be different or because parents treat them differently, see Bound and Solon (1999) for further references. Blanchflower and Elias (1996) find differences in schooling ability within twin pairs, comparing a relatively small number of twins from the British Child Development Study. Moreover, if parents recognise that twins are different, they may take steps to compensate and encourage schooling for one of them. Different treatment from parents may bias the return from schooling estimates in either direction.

In our context, these (often small) differences in character, attitude, cognitive ability or events during childhood and adolescence may be important factors behind the (often small) differences in schooling. Moreover, these characteristics or experiences *may* also affect earnings capacity and expected return to schooling, see the discussion in Bound and Solon (1999).[3] In this case, the PFE assumption does not hold. As pointed out by Griliches (1979) twenty years ago, the

3. In the words of Bound and Solon (1999) "Any parent of monozygotic twins will tell you that their kids do differ in temperament and abilities. Often these differences are subtle, but presumably it is these differences, rather than coin flips, that account for the twin's divergent choices about schooling. And, if the same differences in temperament and abilities also exert other influences on wages, the empirical association of the between-twins wage difference with the between-twin schooling difference reflects more than just the causal effect of the latter on the former".

twin-based estimate is closer to the true average marginal return to schooling, if and only if, the endogenous variation in educational attainment comprises *a smaller share* of the between-twin variation in schooling than it does of the between-families variation, see also Card (1999). Unfortunately, it is not sufficient that twins are more similar than a random pair of observably equivalent persons!

However, if we were confident that (i) the correlation between earnings capacity (a_j) and schooling (S_j) is zero or positive and that (ii) individuals with high return tend to invest more in educational attainment, the twin-based estimates are useful even if the PFE-assumption is violated. Under these conditions, the standard OLS and the first-difference within-family estimate will both be upward biased. Therefore, one can argue that a twin-based estimate which turns out to be lower than the OLS-estimate has tightened the upper bound on the (average) return to schooling. This argument is only valid if schooling is measured correctly, since measurement error typically creates a downward bias which is larger for the within-family than the OLS-estimator, see discussion in Bound and Solon (1999) or Card (1999).

Some studies have backed up the PFE assumption by means of indirect evidence. One strategy is to compare within-pair and across-pair correlations between schooling and observed characteristics (Z) that correlate with earnings ability. Twin approach supporters would like to find, first, a significant across-pair correlation between S and Z and, second, no within-pair correlation based on regressing schooling differences on differences in Z's like schooling of spouse or physical/psychological characteristics. Ashenfelter and Rouse (1998) perform such tests and conclude that the PFE assumption is likely to hold in their data. In light of the difference between Scandinavian countries and the US in wage structure, educational institutions and intergenerational earnings mobility, see Björklund and Jännti (1997), one might find US-based studies to be of limited interest for Norway. The results by Iscasson (1999a) on Swedish twin data are more relevant since Sweden and Norway are fairly similar, both in terms of labour market characteristics and educational institutions. Isacsson (1999a) tests the equal within-pair ability assumption by comparing between-pair and within-pair correlations between years of schooling and two physiological characteristics (birth weight and height) of the individual and between schooling and two psychological measures of the individuals personality. The general findings are that correlations were stronger in the between-pair than in the within-pair estimations. Isacsson (1999a) interprets this as supportive evidence for the assumption of randomly determined differences in schooling between twins of the same family.

Finally, the validity of twins-based estimates are questioned because twin samples are rarely proven to be representative for the population at large. Twins can be different from non-twins. Blanchflower and Elias (1996) "presents evidence which suggest that there are significant differences between twins and non-twins in terms of measured ability (i.e test scores at the age of 7,11 and 16), schooling and economic gain from years of schooling". Ashenfelter and Rouse (1998) show that the twins of the Princeton Twinsburg study and their parents are better educated, have higher wages, are more likely to be covered by a union and, most importantly, have a higher OLS-estimate of return to schooling. The 680 twins are compared with a similar Current Population Survey (CPS) sample and the General Social Survey in 1990–1994.

The practical difficulties associated with

the collection of twin data can reduce representativity. One might argue that twin study estimates of returns to schooling can be generalised only if twins are representative with respect to observable individual and family characteristics *and* if simple schooling-earnings correlations (i.e. OLS estimates) are similar. Our study meets both these requirements. The sample of twins and non-twins are practically identical, in both respects.

The literature reveals that researchers have different opinions about the extent to which twin studies are useful to disclose, and correct for, a potential ability bias. While researchers who have invested heavily in the construction of twin data believe in the PFE assumption, others are sceptical.[4]

Previous studies

The average hourly wage premium associated with an extra year of schooling in Norway is typically estimated to be around by 4.5–6.0 per cent, see a recent review of Barth and Røed (1999).[5] The effect of schooling on earnings is lower in Norway than in most other countries. For example, OECD (1997) finds that among a large number of OECD countries, Norway has the lowest internal rate of return from completing a university degree.

The low return to schooling in Norway relative to most other countries, can be given different explanations. First, educational attainment has increased remarkably in Norway during the last 20-30 years and these supply shifts are likely to reduce relative wages of better-educated employees. Second, the high degree of centralisation and the focus on solidaristic wage policies are commonly seen as important explanations for the low and stable wage dispersion in Norway, see Kahn (1998), Moene and Wallerstein (1997), Freeman (1996). Norwegian labour market institutions tend to raise wages of the less educated and also keep earnings of university graduates down. Third, the large public sector, in which pay is lower than in the private sector, employs a high fraction of those with high levels of education. Finally, the low effect of schooling *may* reflect that the ability bias is less important in Norway than in other countries. As described in the previous sections, ability bias is closely related to the existence of heterogeneity with respect to earnings capacity and returns to schooling. A speculative conjecture is that a society with fairly equal distribution of earnings, wealth and opportunities due to a very low school/university fees combined with universal access to student loans and grants, will generate a weaker correlation between innate ability to succeed in the labour and educational attainment.

Few previous Norwegian studies have attempted to account for ability bias when estimating returns to schooling, see Barth and Røed (1999).[6] Hægeland, Klette and Salvanes (1999) is an exception, where the region in which the person grew up and parental educational attainment are factors deter-

4. A speculative interpretation is that personal interests and experience colour researchers' attitude. According to Card (1999), Becker (1964) suggests that scholars are biased in their opinion since they appreciate the idea that ability is a major cause of the high earnings received by college graduates (like themselves). On the other hand, as a parent of twins you are likely to object to the idea that your children have identical capacities and that "random" events explain why one of them stayed longer in school.
5. Studies on annual earnings typically estimate somewhat higher premiums, 6–7 per cent.
6. Schooling careers has been studied extensively in Norway and mainly by sociologists. A recent study by Nordli Hansen (1997) shows that parental income at the age 10–14, conditional on class background measured by the occupation of father, has a fairly strong effect on educational attainment at all levels.

mining the schooling level. The region is used as an instrumental variable, assuming the regional affiliation during childhood exerts no direct influence on earnings as adult. The inclusion of generalised residuals from an ordered probit equation of educational choice into the estimated wage (earnings) equation seems to a have a modest effect on the estimated return to schooling. They find that OLS estimates are downward biased, but the upward adjustment following from the IV-estimator is minor.

The similarity of Norway and Sweden justifies references to recent Swedish studies controlling for ability measured by intelligence scores, achievement tests and school marks at the age of 12–13. Kjellström (1997) finds that the estimated wage effect of one extra year of schooling falls by 20 per cent when ability measures are included. Meghir and Palme (1999) show that the inclusion of ability measures reduces the annual return to schooling by a similar magnitude.

Recent twin studies from various countries include Behrman et al (1994), Behrman and Rosenzweig (1999) on the Minnesota Twins Registry, Ashenfelter and Krueger (1994) and Ashenfelter and Rouse (1998) on the Princeton Twinsburg Study (PTS) in the United States, Miller, Mulvey and Martin (1995),(1997) use the Australian Twin Registry and Isacsson (1999a,b) is based on the Swedish Twin Registry. The general finding of these studies is that OLS estimates are (slightly) upward biased, depending on adjustments for measurement error in the schooling variable.[7] In some cases, the ability bias disappears when measurement errors are taken into account.[8] The famous exception is Ashenfelter and Krueger (1994) who found a strong negative ability bias. This conclusion turned out to be wrong and due to sampling error, see Ashenfelter and Rouse (1998) and Rouse (1999). Miller, Mulvey and Martin (1997) is the only study reporting gender-specific results. They find a considerably greater family background effect for males than for females, leading to the conclusion that "the pure returns to schooling are greater for females than for males", p. 133.

The Norwegian data of twins

While twin samples usually come from surveys based on Medical Birth registers, or even twin assemblies like the PTS, our data are established by a matching of several official registers of Statistics Norway. The registers cover all residents in Norway aged 16–69 and include information on day of birth and a link to parents. Twins are defined as individuals born at the same, or the next/previous, day by the same mother. Our twin pairs are biological twins, not necessarily reared together and we do not know whether they are monozygotic or dizygotic. An application Weinberg's rule[9] indicates that approximately half of our twin pairs are monozygotic. The register matching procedure seems to identify about 80 percent of Norwegian twins born 1946–1965, see Raaum and Aabø (1999) for further details.

7. Summaries with more details are given in Card (1999), Bound and Solon (1999) as well as in Ashenfelter and Rouse (1999).
8. It should be noted, however, the measurement error corrections rely on very strong assumptions, see Kane, Rouse and Staiger (1997). The popular strategy to instrument schooling by means of reports from the other twin has recently been questioned by Neumark (1999) and Bronars and Oettinger (1999).
9. This is essentially saying that since approximately half of the non-identical twin pairs have the same sex, we can estimate the total number of identical twin pairs by deducting the actual number of pairs of different sex from the number of same sex pairs.

Our schooling variable is the *highest* level of educational attainment by October 1993, according to the official Norwegian education register. This register is updated on the basis of information from schools/universities and covers completed degrees and exams from courses of at least 300 hours, given by officially approved schools and universities. The "years of schooling" variable is defined by the register as the standard number of years associated with a specific type of education.[10] The education attainment variable is then a measure of formal qualifications, rather than the *actual* years of schooling completed by the individual.

Parallel analyses are conducted on annual and hourly earnings. Annual earnings is the total sum of wages, salaries and sick-leave plus maternity-leave payments. Unemployment benefits are not included. Hourly earnings are based on wages and salaries, including taxable fringe benefits, in a matched employee-employer relationship.[11] Earnings are measured as the average of 1992 and 1993, both for annual and hourly earnings.

The samples are restricted as follows. First, those who completed their schooling during 1992 or 1993 are excluded. Second, the sample is restricted to those who earned at least 36167 NOK in 1992 and 37033 NOK in 1993. This minimum amount is equal to the threshold qualifying for pension rights in the public age pension system ("Folketrygden"). Third, to concentrate on wage earners, individuals are excluded if self-employment income amounts to more than 10 per cent of annual earnings. The person-specific control variables (the X_{ij}) include actual work experience, region, marital status, child born in 1991,1992 or 1993, and the number of children aged 2–6 and 7–16 by end of 1992.[12] The number of twin-pairs of the same sex we use in the estimations are 3 431 (annual earnings sample) and 2 325 (hourly earnings sample). Analyses are restricted to twins aged 28–47. The exclusion of younger twins ensures that the vast majority of the each cohort has completed their schooling, while the exclusion of twins over 47 is due to low coverage of twin pairs in the data born before 1946. The sample reductions due to the various restrictions are shown in Raaum and Aabø (1999).

The representativity of the twin sample is studied in Table 1. Means for non-twins are based on a random sample of individuals drawn from the same data source as the twins and stratified by age and gender.[13] There are only minor differences between twins and non-twins. Mean earnings are very close. While female twins have slightly more schooling than non-twins, the opposite holds for males. As far as individual characteristics are concerned, means of twins and non-twins are very similar.

Table 2 shows how educational attainment varies within twin pairs. The twins have the same number of schooling years in approximately 4 out of 10 families. The mean difference is 1.4 years for men and about 1.3 years for women. The within-pair correlation in years of schooling is 0.58 for men and 0.67 for women. These correlations are very similar to the numbers reported in other twin studies,

10. A school reform gradually introduced 9 years of compulsory in the 60'ies and early 70'ies. Seven or eight years of schooling is upgraded to nine in our analysis, but this corrections had negligible effects on the results.
11. Details on the construction of hourly earnings are given in Raaum and Aabø (1999).
12. Raaum and Aabø (1999) contains more information on the controls and sample restrictions.
13. The non-twins are drawn from the annual earnings sample and one hundred individuals are drawn for each twin pair.

Table 1.
Individual characteristics of twins and non-twins. 28-47 years. Hourly earnings sample. Standard deviations in parentheses.

	Male Twins	Non-Twins	Female Twins	Non-Twins
Number of individuals	3112	168836	1538	105124
Age 31.12.93	37.5	37.31	37.15	37.11
	(5.58)	(5.63)	(5.67)	(5.64)
Married 1.1.93 (yes=1)	0.6160	0.6232	0.5618	0.6059
Women who gave birth 1993	-----	-----	0.0585	0.0621
Child born in 1992 (yes=1)	0.0749	0.0739	0.0540	0.0540
Children 1–6 years 31.12.92 (yes=1)	0.3554	0.3771	0.2633	0.2947
Children 7–16 years 31.12.92 (yes=1)	0.4441	0.4462	0.3901	0.4418
Years of schooling (mean, 9-20 years)	11.86	12.10	12.09	12.00
	(2.35)	(2.47)	(2.44)	(2.43)
Completed education 1990–91 (yes=1)	0.0537	0.0496	0.0618	0.0638
Ln (mean annual earnings 92–93)	12.4080	12.4247	12.1135	12.0706
	(0.3155)	(0.3252)	(0.2999)	(0.3121)
Ln (mean hourly earnings 92–93)	4.8401	4.8611	4.6736	4.6531
	(0.3037)	(0.3223)	(0.2886)	(0.3101)
Years of work experience 1967–91	16.26	15.87	13.34	13.02
	(5.61)	(5.61)	(5.02)	(5.14)

taking into account that our sample is an equal mix of both monozygotic and dizygotic twins. The earnings correlation is higher for annual than hourly earnings, presumably reflecting a labour supply effect of family background.

Compared to other twin studies, we find lower earnings correlations in our data. This can be explained in various ways. First, since the age span in our data is tighter than in other studies, the common age or work experience factor shared by twins is less important. Second, the higher earnings correlation in other studies can also be explained by to the use of average occupational group earnings and stricter sample inclusion criteria, for Miller at al (1997) and Isacsson (1999a) respectively. Finally, the lower correlation our data may simply reflect that family background explains a smaller part of the earnings variation in Scandinavia than in the U.S, Björklund and Jännti (1997).

To conclude the data description, we summarise what we see as the attractive features, and also, some drawbacks of our data. Sampling error or attrition is unlikely to bias our results. We find that twins are representative, using the same information set for twins and non-twins. By the use a two-year average of earnings, we reduce the potential problem of transitory components. Finally we have a fairly large sample, allowing for separate analyses of men and women. On the other hand, the data also have shortcomings. They offer no opportunity to distinguish between monozygotic and dizygotic twins. Moreover, we do not have a second source of information on educational attainment, which could help us to adjust for possible measurement error. However, the schooling variable as a measure of formal educational qualifications is likely to be of high quality. Measurement error is probably less frequent in register data than in self-reported surveys.

Table 2.
Within-pair correlations in schooling and earnings. Hourly earnings sample.

	Male	Female
Number of pairs	1556	769
Fraction with same years of schooling	0.3811	0.4161
Differences in years of schooling:		
1 year	0.2423	0.2588
2 years	0.1716	0.1170
3 years	0.1015	0.1092
4 years	0.0456	0.0533
5 years	0.0263	0.0260
6+ years (6-9 years)	0.0315	0.0195
Mean (incl. zero)	1.4094	1.2848
Standard deviation (incl. zero)	(1.6123)	(1.5235)
Within-pair correlations in:		
Years of schooling	0.5848	0.6669
Ln (mean annual earnings)	0.4042	0.3199
Ln (mean hourly earnings)	0.3554	0.2748

Estimated effects of schooling on earnings

In the model outlined above, an additional year of schooling is assumed to have the same effect on (log) earnings at all levels of educational attainment. We also estimate a more flexible model with separate dummies for years of schooling beyond the compulsory nine years. A non-linear model also allows the ability bias to vary across different levels of educational attainment. We expect larger effects of schooling on annual than on hourly earnings, simply because working hours tend to be higher for more educated persons.[14]

The main results of the linear model are given in Table 3 and the standard cross section estimates (OLS) are presented in the two top rows. The first row contains the estimates for non-twins. By comparing non-twins and twins (second row), we find that the twin samples are highly representative. The OLS-estimates of the linear model are indeed very similar for non-twins and twins, when we ignore the common factor(s) shared by twins. This similarity holds for all four combinations of gender and earnings definition.

The OLS estimates of twins and non-twins differ at most by 0.0013.[15] The OLS

14. By construction, log (annual earnings) = log (hours worked during the year) + log (hourly earnings), although the exact decomposition is impossible in our data due to lack of detailed hours information. Thus, the annual earnings effect of schooling is the sum of the effect on hourly earnings and the effect on hours worked. Estimates from the mid-1990's in the U.S. indicate that one third of the annual earnings effect arises from hours and two thirds from hourly earnings, see Card (1999).
15. In simple OLS regressions on the pooled samples of twins and non-twins, we find that the twin dummies and the interaction terms twin*schooling are far from significant (t-values well below one).

Table 3.
Estimated average marginal return to schooling. Twins and Non-twins. Linear model.

	Annual earnings		Hourly earnings	
	Men	Women	Men	Women
Non-twins (OLS)	**0.0612**	**0.0713**	**0.0487**	**0.0435**
	(0.0003)	(0.0004)	(0.0003)	(0.0004)
Twins (OLS)	**0.0616**	**0.0700**	**0.0500**	**0.0435**
	(0.0024)	(0.0027)	(0.0022)	(0.0030)
First difference or fixed effect model (FE)	**0.0363**	**0.0579**	**0.0280**	**0.0400**
	(0.0048)	(0.0059)	(0.0046)	(0.0064)
Difference (OLS-FE)	*0.0253*	*0.0121*	*0.0220*	*0.0035*
SURE-model				
Own education	**0.0375**	**0.0551**	**0.0319**	**0.0395**
	(0.0043)	(0.0058)	(0.0041)	(0.0062)
Sum education	**0.0154**	**0.0093**	**0.0115**	0.0026
	(0.0025)	(0.0032)	(0.0024)	(0.0035)

Controls included: Years of work experience (actual), marital status, children, recently completed education, and region. Bold numbers indicate significance at 5 percent level.

estimates of the average marginal return to schooling are also very close to what is found in previous Norwegian studies. Second, the estimates confirm that the effects on annual earnings exceed those on hourly earnings. The effect of schooling on annual earnings seems to be stronger for women than for men, while the effect on hourly earnings is somewhat larger for men. Taken together, this indicates a larger labour supply effect of schooling among women. Control variables are all reasonably signed, see details in Raaum and Aabø (1999). Marriage is associated with higher earnings for males, but married men do not have higher hourly earnings. Married women earn less per year than unmarried females but no difference appears for hourly earnings. Children have no impact on male earnings. Women with children below 16, however, have considerably lower annual earnings than other female employees. The earnings premium per year associated with an extra year of work experience is about 1.1 for men and 2.1 per cent for women, evaluated at the average years of experience. The marginal effect of experience on *hourly* earnings is more similar and around 0.9 per cent for both men and women.

We present two alternative within-family estimators. The estimates of the first-difference or fixed effect model (FE), are shown in row three. An alternative procedure, suggested by Ashenfelter and Rouse (1998), includes total years of schooling in the earnings equations to capture the common family component shared by twins. The estimates of this SURE model are shown in rows four and five. The magnitude of the

ability bias is measured by the coefficient for the twins' total years of schooling.

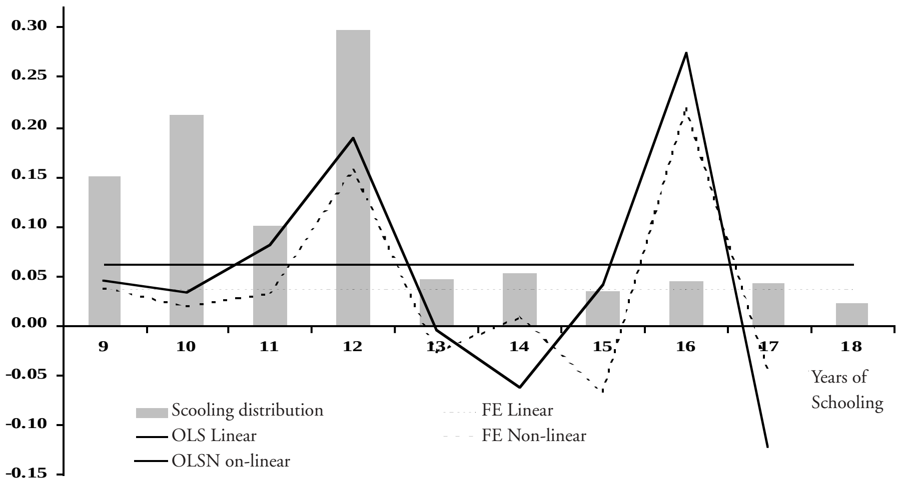
For men, there is clear evidence of a *positive ability bias*. The estimates of the FE and SURE models are both substantially lower than the corresponding OLS estimate. The ability bias is statistically significant since we can reject the null that the coefficient for total years of schooling is zero in the SURE model. While the standard OLS annual earnings effect is about 0.062, the FE and SURE-estimates are similar and about 0.037. The estimates based on hourly earnings show the same pattern. The standard OLS estimate of 0.05 is reduced to around 0.03 taking into account the heterogeneity of family background. The ability bias is only slightly higher for annual than for hourly earnings, indicating that the reduction in the estimated casual effect of schooling is due to unobservables which impact hourly wages rather than factors related to unexplained variation in hours worked. We should emphasise that the positive ability bias can be due to heterogeneity of earnings capacity as well as differences in returns to schooling *across families*, as explained above.

The within-family estimates reveal that the ability bias is different and less important for women. First, no bias is found for hourly earnings, since the first-difference (FE) as well as the SURE estimate of own schooling are both very similar to the OLS. The sum of schooling years does not have any significant effect on hourly earnings. Looking at annual earnings, however, the standard OLS estimate is upward biased since both the FE and the SURE estimates are lower than the OLS. The total years of schooling variable has a significant effect on annual earnings. The average marginal effect of schooling falls from 0.070 in the OLS to 0.058 in the first-difference model (FE). The estimate of the SURE model is 0.055. The positive ability bias found for annual earnings, combined with the absence of bias for hourly earnings, suggests that family background affects hours worked *and* schooling.

An alternative interpretation of the difference between the standard OLS and the within-family estimates is that schooling is measured imprecisely. As pointed out by Griliches (1979) and numerous recent studies like Card (1999), the downward bias induced by measurement error is *exacerbated* using within family estimators. We have no access to instruments or information about the reliability ratio to correct for possible measurement error.[16] However, we believe that measurement error is a minor problem in the educational registry. Moreover, the difference in predicted ability bias between men and women is not consistent with measurement error being the sole reason. Measurement errors, if they are widespread, should be of similar magnitude for men and women. Therefore, within-family estimates should be lower that the standard OLS for both men and women. Thus, the similarity of the standard OLS and within family estimates for *female hourly earnings* means that the *"true" ability bias must be negative to cancel out any attenuation caused by measurement error*. Since we are fairly confident that the ability bias is non-negative, we conclude that measurement error is unlikely to be the major explanation for why within-family estimates are lower than the OLS. Moreover, if

16. See Neumark (1999) for a critical discussion of IV-based within-twin estimates which claim to adjust for measurement errors. Neumark argues that "Although AK's (Ashenfelter and Krueger (1994)) IV estimator eliminates measurement error bias in the within-twin estimate, it amplifies the omitted variable bias from any differences within pairs, possibly substantially", p. 145.

Figure 3.
Men. Annual earnings. Marginal effects of one year of schooling and schooling distribution.



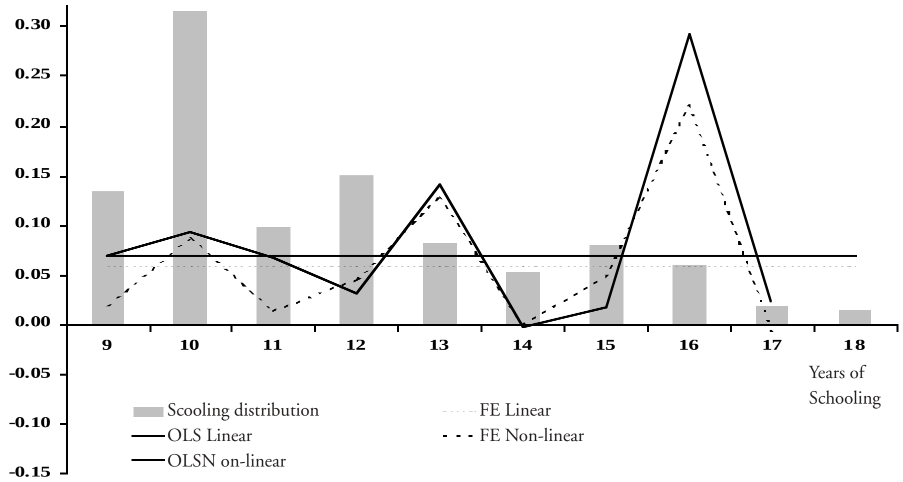
measurement error attenuation of the schooling effect is important, the within family estimates for women should be lower, relative to the OLS, compared to men. We find exactly the opposite.[17]

We also estimate a flexible non-linear model with dummies for years of schooling (9 through 18–20), motivated by previous Norwegian studies that find very low marginal returns to medium-long higher education. A potential explanation for this non-linearity is that ability bias varies according to level of schooling. We start with the results for men. Figure 3 contains estimates of four different models (linear/non-linear and OLS/FE model) and the distribution of educational attainment in the histogram, for the annual earnings sample.[18] The lines indicate *the marginal effects*, i.e. the earnings differential associated with an additional year of schooling at different levels of educational attainment. To facilitate a comparison with the linear model, the horizontal lines represent the estimates from Table 3. Consider first the OLS estimates where family (twin) relations are neglected. First, we note that the marginal effect is above the average marginal effect from the linear model at 11, 12 and 16 years of schooling.

One extra year at eleven years typically involves completing upper secondary schooling (high-school graduate) while 13 years involve some college or university training. Thus, men who take some post-

17. The attenuation of the schooling effect is related to within-pair correlation in schooling, see e.g. Card (1999), which is higher for women, see Table 2.
18. The pattern for hourly earnings is virtually identical, see Raaum and Aabø (1999) which also contains the detailed estimates.

Figure 4.
Women. Annual earnings. Marginal effects of one year of schooling and schooling distribution.



secondary education receive a substantial earnings premium. Second, the marginal return at 13–15 years of schooling, i.e. 2–4 years of college/university education is low and even negative, although not significantly different from zero. On the other hand, the earnings gain from completing a 5–6 year university degree (at the Masters level) is above 20 per cent and highly significant. The estimates of the fixed effect model confirm the positive ability bias found for men in the linear model. Except for 14 and 17 years, where the marginal effects of the non-linear OLS model are negative, the within-family estimates are lower. The marginal effects at 12 and 16 fall somewhat but remain high. Two main conclusions can be drawn. First, the relationship between schooling and male earnings is characterised by a low and even negative marginal effect of 2–4 years of post-secondary education. The linear model is rejected by standard parameter restriction tests, see details Raaum and Aabø (1999), even for within-family (FE) model. Second, a positive ability bias is also found using the more flexible model.

The results for women are mixed. First we look at *annual* earnings in Figure 4. The linear model indicates a moderately positive ability bias. The linear OLS model tracks the unrestricted model fairly well at the lower end of the schooling distribution, but it clearly underestimates the large earnings premium associated with completing a university degree at the Masters level. Like for men, marginal effects of shorter post-secondary education are mixed. For women, extending higher education from one to two years has a high marginal return, while another year or two have minors effect on earnings. The marginal effects from the FE estimates are close to or below the OLS estimates, confirming the positive bias suggested by the linear model. The linear model seems to be more appropriate for women since a standard parameter restriction test does not reject a constant marginal years of schooling effect, see Raaum and Aabø (1999) for details.

While the earnings measure is of minor importance for the male estimates, the linear model indicated a positive labour supply effect of schooling for women that raised the schooling effect on annual earnings. When we estimate the non-linear model using hourly earnings, the linear OLS underestimates the marginal return at 13 and 16 years. The direction of ability bias indicated by the difference between standard OLS and within family estimates is mixed. This is consistent with no (average) bias in the linear model. The very high marginal return of completing a full university degree (17 years) is reduced when we estimate within families and the low marginal returns of medium long higher education remain.[19]

Conclusions

The effect of schooling on earnings is estimated using a large sample of Norwegian twins, aged 28–47. The estimated average marginal return to schooling obtained from a standard earnings equation contains an ability bias if earnings capacity *or* individual return is correlated with the educational attainment of individuals. The outcomes of twins constitute attractive data which enables us to correct for this ability bias, assuming "Pure Family Effects" (PFE). Under PFE the earnings capacity or/and return are correlated with schooling between families, but the variation in educational attainment within twin pairs is due to factors without direct influence on post-schooling labour market performance.

We show that our sample of Norwegian twins is representative. There is no difference between twins and non-twins in the standard OLS estimates of returns to schooling or individual characteristics. The main findings can be summarised as follows.

Standard OLS-estimates show that an additional year of schooling is associated with an *annual* earnings increment of about 6 and 7 percent, for men and women respectively. The effect on hourly earnings is about 4.5 percent for both men and women. We interpret the higher effect on annual earnings as a consequence of a positive correlation between schooling and hours worked.

We first summarise and offer an interpretation of the results for men. The within family estimate of the effect of schooling on *hourly* earnings is found to be 3 percent, compared to a standard OLS estimate of about 5 percent. The reduction in the schooling effect, interpreted as a positive ability bias, is about the same for hourly and annual earnings (for earnings per year, it falls from 0.062 to 0.037), indicating that family background has a limited direct effect on male labour supply. The positive ability bias for male hourly earnings can be explained in several ways. First, it may reflect that individuals from families with high returns to schooling choose, or are allowed, to take more schooling. Second, the marginal costs of schooling, both pecuniary and non-pecuniary, may be lower for individuals with characteristics that are positively rewarded in the labour market. Examples of such characteristics are motivation, work effort capacity, ability to solve problems or work in teams, etc. These characteristics are likely to affect the sorting of employees into high- and

19. The estimates of the female non-linear FE-model are not precisely determined and we are unable to reject the linear model, see Raaum and Aabø (1999) for further details.

low-paying firms, careers within firms and the content of individual wage contracts. Moreover, these characteristics may also affect educational choice. The key idea behind our approach is that twins are similar with respect to all these individual characteristics.

Limited access to colleges and universities may also generate a correlation between earnings ability and the level of schooling. Studies from other countries, including Sweden, suggest that test scores and school performance are positively correlated with adult earnings. The rationing of slots in colleges, universities and even in the upper secondary school is largely based on previous school performance. Consequently, individuals who have been denied access to schools are on average those with weaker school performance and earnings ability. Opportunities are likely to vary more between individuals from different families than between twins from the same family.

The results are different for women for whom we find no indication of ability bias in the estimate of schooling effects on *hourly* earnings. For female annual earnings, however, the within-family estimate is lower than the standard OLS estimate, 0.056 and 0.070 respectively. This suggests a positive "hours-bias" where family background influences educational attainment and post-schooling labour supply of women. The Becker-type optimal schooling model predicts that women who plan to work more hours, stay longer in school. For a given hourly wage premium, the economic return to schooling is positively related to the expected number of working hours after completing ones education. If family background is an important determinant of women's position within the family (home production, child care etc.), we would expect to find a positive *annual* earnings ability bias, arising from heterogeneity of returns. Because the variation in working hours is much lower for men, this effect is far less important for men.

The absence of ability bias in the OLS estimate of schooling effects *on female hourly earnings* is striking. Several possible explanations can be given. Although women tend to have about the same length of schooling as men, the content of their education differ and they qualify for other jobs than men. Men are more likely to take jobs in the private sector and in firms with individual pay determination. Since women are over-represented in the public sector where wages are set by collective bargaining, personal characteristics are likely to have less impact on female wages. Our results are also consistent with the view that women are less motivated by economic returns when they make choices about educational investments. Moreover, women may have stronger preferences for other job characteristics, like flexibility, than men. Finally, non-random selection into the labour force could reduce the correlation between schooling and ability for women. For example, innate ability and schooling could both affect female wage opportunities, but not their value of non-market activities. Then, self-selection will tend to result in female labour force participants with low levels of schooling having higher innate ability than better-educated women. Even if schooling is positively related to earnings ability for all women of a given cohort, this correlation diminishes and may even disappear when we restrict ourselves to labour force participants. Since male labour force participation rates are higher and vary less across educational groups, such composition bias is less important for men.

The marginal effect of schooling on earnings is not the same for different levels of educational attainment, although the rejection of the linear model is less clear for women. The very low return associated with

3 or 4 years of higher education remains after having controlled for family background.

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